HUMAN BIOLOGY

a record of research

SEPTEMBER, 1937

Vol 9 No 3

PUBLISHED QUARTERLY BY
THE JOHNS HOPKINS PRESS, BALTIMORE, MARYLAND, U.S.A.

HUMAN BIOLOGY

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HUMAN BIOLOGY is published quarterly by The Johns Hopkins Press, Baltimore, Maryland, U. S. A. The advance subscription price is $5.00 a year (foreign postage 35 cents; Canadian 13 cents). Single current issues are $2.00 each; back numbers, $3.00 each; back volumes, $6.00; plus postage. Subscriptions for less than a year are charged at the single issue price.

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Manuscripts and communications regarding editorial matters should be addressed to Editor, Human Biology, 1901 E. Madison St., Baltimore, Maryland, U. S. A.

THE JOHNS HOPKINS PRESS, *Publishers*
BALTIMORE, MARYLAND, U. S. A.

Entered as Second Class matter, February 18, 1929, at the Post Office at Baltimore, Md., under the Act of March 3, 1879.

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7-2440

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VOL. 9 No. 3

PROPORTIONS, VARIABILITY AND ASYMMETRIES OF THE LONG BONES OF THE LIMBS AND THE CLAVICLES IN MAN AND APES

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INTRODUCTION

THE anthropological literature contains a mass of detailed information on the degrees of variability of many structures of the human body. Comparative data, however, on the variability of corresponding parts in the animal body are still quite inadequate for a comprehensive and reliable evaluation of the findings for man. In regard to asymmetries, or variations in the two halves of the body, we also possess infinitely more data for man than for animals, and it has been as yet impossible to compare human asymmetries with adequate series of observations on asymmetries in more than a few animals. That data on apes and monkeys are most desirable for such comparisons with the conditions in man is a matter of course. In consequence of this extremely uneven advance in our knowledge of variability and asymmetry there still persist the wide-spread, but unproved, assumptions that civilized man is more variable than are wild animals of one and the same species and that asymmetries in general are much more common in man than in other primates.

The present paper contributes chiefly new data on variability and asymmetry for comparisons between some civilized and uncivilized races of man and for comparisons between man and other primates, particu-

larly the anthropoid apes. These data have all been obtained with the same technique and, with few exceptions, by the same observer, the author. After having taken the measurements, primarily intended for the study of variability and asymmetry, data became available which yielded also new information on some proportions between the lengths of the long bones of the limbs. While measuring the humeri the occurrence of septal apertures was recorded so that the frequency of this condition can be briefly listed as a by-product of this investigation. No systematic attempt is made to compare the results of this study bearing upon racial differences in man with all the many corresponding data in the literature on human races. The author is concerned primarily with providing new and uniformly taken records for comparisons between man and the apes, so that it will become possible later on to interpret on this basis the more detailed differences between the various subdivisions of man. The chapter on asymmetries will be restricted to the presentation of the facts found and to the direct conclusions therefrom and will omit intentionally any lengthy review and discussion of the many, varied, and more or less plausible theories appertaining to asymmetrical size and function in the human body.

In a previous paper the author (1930) had already dealt tentatively with the questions which form the subject of the present study. The material available for this former publication was too scanty to produce the much needed information in regard to the really representative variability and asymmetry in apes. During the last seven years the author has used every opportunity to increase his series of data for the study of variations and asymmetries in higher primates. Table 1 shows that it has been possible to add observations on more than one thousand skeletons not previously examined by the author. Approximately one half of these new records have been collected in the Hamann Museum of Comparative Anthropology and Anatomy of Western Reserve University with its admirably extensive series of skeletons of whites and Negroes and of gorillas and chimpanzees. The writer is greatly indebted to Prof. T. W. Todd for his generous permission to study the wealth of material in the Hamann Museum and for the hospitality of his laboratory. Over three hundred skeletons, not previously utilized by the author, were measured in the United States National Museum. In the Division of Anthropology Dr. A. Hrdlička very kindly made avail-

TABLE 1

List of adult primate skeletons examined for this investigation. The human skeletons total 753 and the ape and monkey skeletons 530

(* = 1 specimen each from Zoological Museum, University Zürich and Laboratory of Compar. Pathology, Philadelphia Zoological Society; ** = 1 specimen each from Royal College of Surgeons, London and Anatomy Department, Columbia University. The determination of the sex of the skeleton of gibbons and siamangs is at best uncertain and many specimens have no data on sex.)

PRIMATE \ COLLECTIONS	SPECIMENS ALREADY LISTED BY SCHULTZ, 1930	HAMANN MUSEUM, WESTERN RESERVE UNIVERSITY	U. S. NATIONAL MUSEUM	LABORAT. PHYS. ANTHROP., HOPKINS UNIVERSITY	COLLECT. A. H. SCHULTZ	AMERICAN MUSEUM NATURAL HISTORY NEW YORK	MUSEUM COMPAR. ZOOLOGY HARVARD UNIVERSITY	PHILADELPHIA ACADEMY NATURAL SCIENCE	VARIOUS COLLECTIONS (one specimen from each)	TOTAL ♂	TOTAL ♀	TOTAL ♂+♀
White.....	11	216	..	5	..	..	..	..	..	122	110	*232*
American Negro ..	11	213	..	9	..	..	..	..	..	122	111	*233*
North American Indian	..	..	117	1	..	..	..	..	..	64	54	*118*
Alaskan Eskimo...	..	..	122	..	..	..	..	..	..	73	49	*122*
Chinese	..	..	40	1	..	..	..	..	..	39	2	*41*
Australian.....	..	..	4	..	..	3	..	..	..	4	3	*7*
Gorilla.....	61	80	2	..	..	8	12	2	..	100	65	*165*
Chimpanzee	29	50	..	6	..	20	2	..	..	45	62	*107*
Orang-utan	66	7	1	1	..	3	..	..	2*	41	39	*80*
Gibbon & Siamang	39	2	16	1	3	8	..	..	2**	?	?	*71*
Macaque	4	..	12	50	41	..	..	..	..	40	67	*107*
TOTAL.....	*221*	*568*	*314*	*74*	*44*	*42*	*14*	*2*	*4*			*1283*

able the unique series of skeletons of North American Indians[1], Alaskan Eskimos and Chinese. In the Division of Mammals Mr. G. S. Miller, Jr. placed at the writer's disposal, as so often before, the extensive skeletal material of apes and monkeys and arranged that the limb bones of many gibbons, previously left in the dried skins, were removed for study. In the constantly growing collections of the American Museum of Natural History the author measured a considerable number of skeletons, not examined by him before. He is greatly indebted to Dr. H. L. Shapiro for permission to study the anthropoid material of the former von Luschan collection and to Dr. W. K. Gregory and Dr. H. E. Anthony who generously made available the material in the Departments of Comparative Anatomy and Mammalogy. The writer wishes to express his thanks also to his many colleagues in still other museums who have greatly facilitated his gathering of data on primate material during visits to the collections in their charge.

From Table 1 it is evident that of all higher primates the Hylobatidae are less well represented in collections of primate skeletons than are the great apes. This discrepancy is particularly regrettable in view of the fact that the former are composed of two genera and a considerable number of species.[2] Furthermore, many skeletons of gibbons and siamangs have no record in regard to sex (which is at best uncertain to determine on the skeleton of these apes). For these reasons it has unfortunately been impossible to obtain among Hylobatidae a sufficiently large series of data for specimens of the same known species and sex to warrant the calculation of standard deviations and variation coefficients. Due to the frequent incompleteness of skeletons of gibbons and siamangs a fairly adequate series of data on asymmetries could be obtained only by using the entire family Hylobatidae as one undivided series. In all the other material of apes and monkeys the sex was

[1] The series of North American Indians, used in this study, is composed of 12 ♀ and 11 ♂ Alaskan Indians, 19 ♀ and 32 ♂ Sioux Indians, 14 ♀ and 11 ♂ Algonquin Indians, 5 ♀ and 7 ♂ Arkansas Indians, and 4 ♀ and 3 ♂ California Indians. For the purpose of the present study all these more or less different groups are combined into one series and no attempt is made here to record and discuss any sub-racial peculiarities.

[2] The present series of gibbons is composed of 10 *Hylobates* (*Brachitanytes*) *klossi*, 10 *H. leuciscus*, 9 *H. lar*, 9 *H. pileatus*, 4 *H. agilis*, 3 *H. hoolock*, 2 *H. concolor*, and 3 gibbons of undetermined species. The slight specific differences in some of the limb proportions of gibbons have already been discussed by the author (1933) and will not be repeated here.

definitely known or has been determined with certainty and the species are known with the exception of the chimpanzees.[3] All the specimens selected for this study are fully adult and none shows signs of advanced senility. It must be specially mentioned here that there exists no significant sex difference between the average ages of males and of females in the series of whites and of Negroes, according to an age analysis of this material kindly furnished by Dr. W. M. Krogman. It does not seem likely that the average ages of the two sexes differ appreciably in the other human races or in the apes used in this investigation.

It is interesting to note in Table 1 that in the series of orang-utans the two sexes are about equally represented, whereas in the series of chimpanzees the females are much more numerous than the males and in the series of gorillas the males outnumber the females a great deal. With the exception of five cases these are all wild-shot specimens. These widely differing sex-ratios in the three great apes may indicate the natural conditions or may be due to differing factors connected with the collecting of the specimens in the field. In the case of the gorilla it is well known that the females will run away from the pursuing hunter while the adult male not infrequently charges and gets killed. It must also be considered that the large male gorilla skeleton usually commands a better price than the less spectacular female skeleton. The writer knows, however, of no similar reasons to account for the striking difference between the numerical proportions of the sexes in chimpanzees and in orang-utans.

The totals of the skeletons, as listed in Table 1, appear in some of the later, special tables considerably reduced, particularly in the tables dealing with asymmetries. This is due to the fact that some bones were missing or broken or showed signs of disease or former fractures and hence were not measured. In most of the great apes the writer recorded the occurrence of healed fractures and of marked signs of disease of the

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[3] The great majority of the chimpanzees in the present series are from French Cameroon. All the gorillas of the Hamann Museum and a considerable portion of the other gorilla material come also from French Cameroon. The series of 165 gorillas includes 7 *G. beringei* and 5 *"G. graueri"*, besides 153 *G. gorilla*. The series of orang-utans contains specimens from Sumatra and from Borneo, the two types being probably only sub-specifically separated. The series of 107 macaques is composed of 79 *Pithecus rhesus* (= *Macaca mulatta*), 11 *P. sinicus*, 6 *P. philippinensis*, 3 *P. nemestrinus*, 2 *P. irus*, 2 *P. fuscata*, 2 *P. tibetanus*, 1 *P. mordax*, and 1 *P. speciosus*. The species differences among macaques are not discussed here.

bones which invariably were found affecting the region of a joint and may have influenced the length of the bone. These records are briefly listed in Table 2 and show that chiefly old fractures are surprisingly

TABLE 2

Cases of old, healed fractures and of evident disease processes on the joints of some of the bones of adult, wild great apes

(*f*=fracture; *d*=bone disease. There is a total of 24 fractured bones distributed among 24 skeletons and a total of 11 diseased bones, 7 occurring in 7 skeletons and 2 each in two skeletons. Fractures, therefore, were found in 9 per cent of all the skeletons examined and marked disease processes in 3 per cent.)

PRIMATE		NUMBER OF SKELETONS EXAMINED	HUMERUS	RADIUS	FEMUR	TIBIA	CLAVICLE
Gorilla	♂ ..	75	2*f* ..	.. ..	2*f* ..	2*f* ..	1*f* ..
Gorilla	♀ ..	52	1*f* ..	.. 1*d*	.. ..	1*f* ..	.. ..
Chimpanzee	♂ ..	35	2*f* ..	1*f* ..	1*f* ..	.. ..	2*f* ..
Chimpanzee	♀ ..	49	3*f* ..	.. 1*d*	.. 2*d*	.. ..	.. ..
Orang-utan	♂ ..	23	2*f* 1*d*	1*f* ..	1*f* ..	.. ..	.. 1*d*
Orang-utan	♀ ..	28	.. 1*d*	.. 1*d*	.. 2*d*	1*f* 1*d*	1*f* ..
TOTAL.....		262	10*f* 2*d*	2*f* 3*d*	4*f* 4*d*	4*f* 1*d*	4*f* 1*d*

common among the great apes in the wild state. Of the various bones studied the humerus appears to become more than twice as frequently fractured as any of the other bones. As far as known, none of the human races shows anywhere near as high an incidence of fractures as do the great apes.

The technique of measuring the lengths of the bones used for this investigation is clearly shown by the drawings in Fig. 1. These particular osteometric dimensions correspond as closely as possible to measurements of the same structures as taken on the outer body, so that the former permit at least approximate comparisons with corresponding data obtained on living or embalmed specimens. The measure-

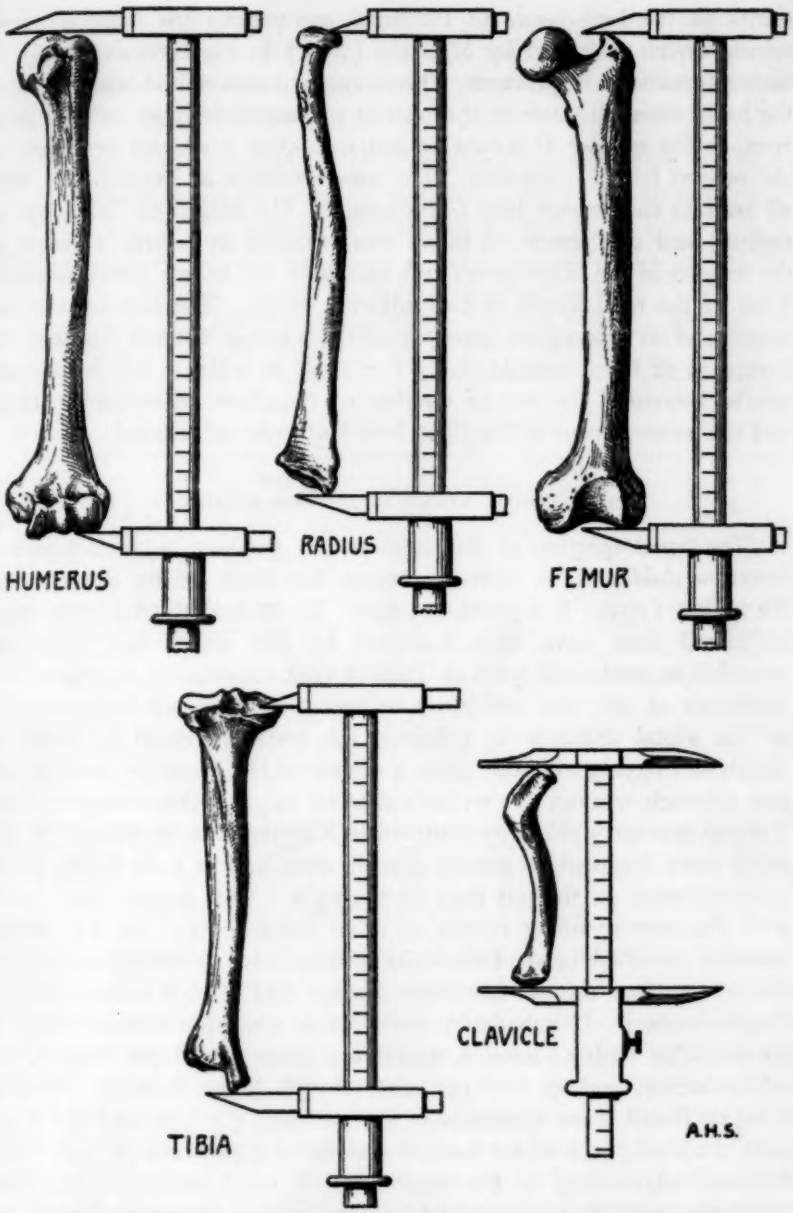

FIG. 1. SEMI-DIAGRAMMATIC REPRESENTATION OF THE METHODS OF MEASURING THE LENGTHS OF THE BONES DISCUSSED IN THIS PAPER

The instruments used are the uppermost section of the anthropometer and the small sliding compass of Martin (1928); the bones shown are those of an adult female chimpanzee. Note that the main longitudinal axes of the bones are always parallel to the measuring rod of the instrument; this is most easily accomplished by bringing the bone as close to the measuring rod as feasible.

ments on the long bones of the limbs are exactly the same as those recommended and used by Mollison (1911) in his extensive study of body proportions in primates. The measurements of the long bones of the limbs were all taken to the nearest millimeter in man and the large apes, in the smaller Hylobatidae and macaques whenever necessary to the nearest half a millimeter. The measurements of the clavicles were all read to the nearest half a millimeter. The length of "humerus + radius" and of "femur + tibia" was obtained by simple addition of the lengths of the single bones and, naturally, not as one direct measurement of the total length of two adjacent bones. The data on absolute length and on proportions appertain to the bones of the *left* side with the exception of those comparatively few cases in which a left bone could not be measured for one or another of the above mentioned reasons, and the measurement of the right bone had to be substituted.

THE SEPTAL APERTURE OF THE HUMERUS

The septal aperture of the humerus (= *foramen supratrochleare* or *intercondyloideum*) in higher primates had been briefly discussed by the author (1930) in a previous paper. In the meantime a great many additional data have been collected by the writer and these are recorded in condensed form in Table 3 (not considering apertures with diameters of only one millimeter or less.) The nature and frequency of the septal aperture in primates has been discussed in detail by Hrdlička (1932), who also gives a review of the literature on this subject (though without the writer's data of 1930). According to Table 3 septal apertures are more common in Negroes than in whites, in both races more frequent in women than in men, and at least in the whites more common on the left than on the right. This agrees quite closely with the corresponding results of other investigators. In the skeletal material of Washington University Trotter (1934) found septal apertures in 4.3 per cent of 960 white humeri and in 12.6 per cent of 784 Negro humeri. If calculated in the same way, the writer's data are considerably higher; namely, septal apertures in 8.8 per cent of 456 white humeri and in 17.0 per cent of 458 Negro humeri. Hrdlička (1932) found these apertures in 6.9 per cent (♂ per cent + ♀ per cent : 2) of 3,354 white humeri and in 18.4 per cent of 196 Negro humeri. According to the recent report by Akabori (1934) these apertures occur in approximately 17 per cent of Japanese humeri and according to the very extensive statistics by Hrdlička in 19.8 per cent

TABLE 3

Percentage frequencies of occurrence of septal aperture in the humeri of the adult primates examined for this investigation

(The human skeletons of the U. S. National Museum have not been included since the septal aperture in this material has already been studied by Hrdlička (1932).)

PRIMATE	SEX	TOTAL OF SKELETONS EXAMINED	SEPTAL APERTURE on right only	on left only	right and left	TOTAL OF SKELETONS WITH APERTURES
White.....	♂	120	0	1.7	3.3	5.0
White.....	♀	108	1.9	5.6	10.2	17.6
Negro	♂	119	5.0	2.5	4.2	11.8
Negro	♀	110	5.5	10.0	19.1	34.5
Gorilla.....	♂	81	8.6	3.7	22.2	34.5
Gorilla.....	♀	50	10.0	2.0	52.0	64.0
Chimpanzee..	♂	38	5.3	0	21.0	26.3
Chimpanzee..	♀	57	5.3	1.8	26.3	33.3
Orang-utan ..	♂	25	4.0	4.0	76.0	84.0
Orang-utan ..	♀	31	3.2	6.5	71.0	80.7
Gibbon.....	♂ ♀	40	0	0	2.5	2.5
Siamang	♂ ♀	10	0	0	0	0
Macaque	♂	40	2.5	5.0	2.5	10.0
Macaque	♀	67	0	0	4.5	4.5

of Eskimos and in 29.6 per cent of American Indians. Among the great apes the apertures are least common in chimpanzees and most frequent in orang-utans and this according to the author's data as well as according to the reports by Slomann (1926) and by Hrdlička (1932). In the author's series septal apertures occur in 39.7 per cent of 262 gorilla humeri, in 27.3 per cent of 190 chimpanzee humeri, and in 77.6 per cent of 112 orang-utan humeri. In the combined series of Slomann and of Hrdlička these percentages are 50.0 for 124 gorilla humeri, 29.5 for 193 chimpanzee humeri, and 73.5 for 130 orang-utan humeri (N.B.: A part of the data by Hrdlička and by the author is based

upon the same specimens). In the Hylobatidae septal apertures are very rare; they were found by the author in only one out of 50 skeletons. In macaques these apertures are also much rarer than in the great apes, being present in only 5.1 per cent of the 214 adult humeri examined. According to Trotter (1934) the aperture was present in 23.9 per cent of 92 humeri of "young" macaques. This would indicate that in the macaque the aperture tends to close with advance in age.

THE LENGTH OF THE HUMERUS AND OF THE FEMUR

As far as known the two sexes differ in average size in favor of males in all human races. This is not a universal rule for primates, since at least in the spider monkey the female is on an average appreciably larger than the male (Schultz, 1933). The extent to which the sexes differ in size fluctuates widely among monkeys and apes. It seems very desirable to obtain a precise expression of the relative sex difference in size in the various monkeys and apes, so that these sex

TABLE 4

The absolute and relative sex differences in size in the lengths of the humerus and the femur

(A=average)

SEX DIFFERENCE IN SIZE OF HUMERUS AND FEMUR	HUMERUS		FEMUR		ARITHMET. MEAN OF BOTH PERCENTAGES
	Absolute difference between A	♀ A in % of ♂ A	Absolute difference between A	♀ A in % of ♂ A	
Whites	29 mm.	91.0	35 mm.	91.9	**91.45**
Negroes	26 mm.	92.1	33 mm.	92.6	**92.35**
Eskimos	25 mm.	91.8	28 mm.	93.0	**92.40**
Indians	28 mm.	91.3	39 mm.	91.0	**91.15**
Average for man	27 mm.	91.6	34 mm.	92.1	**91.84**
Gorilla (*gorilla*)	69 mm.	84.2	65 mm.	82.7	**83.45**
Chimpanzee	16 mm.	94.7	14 mm.	95.4	**95.05**
Orang-utan	42 mm.	88.5	35 mm.	87.0	**87.75**
Macaque (*rhesus*)	7 mm.	95.2	9 mm.	94.7	**94.95**

differences in man can be compared with those in other primates. Since it would be exceedingly difficult, if not impossible, to secure statistically adequate series of data on the size and weight of the *entire* bodies of adult male and female great apes, we must utilize instead the large series of skeletons of adult apes in our collections. As has been realized for a long time, the lengths of the long bones of the limbs are the most suitable dimensions on the skeleton for characterizing the general size of the animal. The data obtained for the present study readily permit such a comparison between man and some apes and monkeys in regard to the relative amounts of sex difference in size, as indicated by the

TABLE 5

The length of the humerus (in mm.) of adult primates

(*=500 mm. on right humerus.)

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White.....	♂	122	276 — 371	321 ± 0.98	16.06 ± 0.69	5.00 ± 0.21
White.....	♀	110	240 — 328	292 ± 0.98	15.33 ± 0.69	5.25 ± 0.24
Negro.....	♂	122	278 — 364	329 ± 1.01	16.55 ± 0.71	5.03 ± 0.22
Negro.....	♀	111	265 — 348	303 ± 1.03	16.10 ± 0.72	5.31 ± 0.24
Eskimo.....	♂	73	272 — 335	303 ± 1.13	14.35 ± 0.80	4.73 ± 0.26
Eskimo.....	♀	49	244 — 309	278 ± 1.24	12.91 ± 0.88	4.64 ± 0.32
Indian.....	♂	64	285 — 354	322 ± 1.23	14.68 ± 0.88	4.56 ± 0.27
Indian.....	♀	54	259 — 323	294 ± 1.35	14.72 ± 0.96	5.01 ± 0.33
Chinese.....	♂	39	277 — 334	301 ± 1.45	13.45 ± 1.02	4.47 ± 0.34
Australian	♂ ♀	7	268 — 320	301 ...	....	... ...
Gorilla (*gorilla*)	♂	93	401 — 497*	437 ± 1.52	21.72 ± 1.06	4.97 ± 0.24
Gorilla (*gorilla*)	♀	60	332 — 403	368 ± 1.37	15.71 ± 0.98	4.27 ± 0.26
Chimpanzee....	♂	45	252 — 345	306 ± 1.73	17.32 ± 1.23	5.66 ± 0.40
Chimpanzee....	♀	62	242 — 327	290 ± 1.61	18.76 ± 1.12	6.47 ± 0.39
Orang-utan....	♂	41	320 — 409	365 ± 1.98	18.89 ± 1.40	5.18 ± 0.38
Orang-utan....	♀	39	300 — 355	323 ± 1.42	13.13 ± 1.00	4.07 ± 0.31
Siamang.....	♂ ♀	19	251 — 289	269 ...	....	... ...
Gibbon.....	♂ ♀	50	187 — 252	224 ...	....	... ...
Macaque (*rhesus*)	♂	19	116 — 157	144 ± 1.59	10.34 ± 1.13	7.18 ± 0.78
Macaque (*rhesus*)	♀	60	120 — 148	137 ± 0.47	5.41 ± 0.34	3.95 ± 0.24

lengths of the humerus and the femur. According to Table 4 the various human races differ but very little in the degree with which the males surpass the females in the length of the long bones. Among the 232 skeletons of whites of the author's series the length of the (left) humeri of the females averages 91.0 per cent of the length of the (left) humeri of the males. In the enormous series of 1668 whites, measured by Hrdlička (1932), the corresponding percentage is strikingly similar, namely 91.27. On a general average the humerus and femur of man are approximately 8 per cent shorter in females than in males. In gorilla this figure is slightly more than twice as great, i.e. 16.5, in the orang-utan it amounts to 12.2, but in the chimpanzee and the macaque

TABLE 6

The length of the femur (in mm.) of adult primates

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White.....	♂	122	377—480	434 ± 1.25	20.49 ± 0.88	4.72 ± 0.20
White.....	♀	110	338—455	399 ± 1.49	23.35 ± 1.05	5.85 ± 0.26
Negro.....	♂	122	379—480	449 ± 1.47	24.07 ± 1.03	5.36 ± 0.23
Negro.....	♀	111	355—473	416 ± 1.42	22.20 ± 1.00	5.34 ± 0.24
Eskimo.....	♂	73	354—443	404 ± 1.64	20.77 ± 1.16	5.14 ± 0.29
Eskimo.....	♀	49	308—412	376 ± 1.84	19.21 ± 1.31	5.11 ± 0.35
Indian.....	♂	64	389—477	433 ± 1.76	20.96 ± 1.25	4.84 ± 0.29
Indian.....	♀	54	347—434	394 ± 1.78	19.36 ± 1.26	4.91 ± 0.32
Chinese.....	♂	39	375—453	408 ± 2.03	18.79 ± 1.43	4.61 ± 0.35
Australian.....	♂ ♀	7	378—430	407 ...	....	... ...
Gorilla (*gorilla*)	♂	84	341—423	376 ± 1.27	17.23 ± 0.90	4.58 ± 0.24
Gorilla (*gorilla*)	♀	54	285—352	311 ± 0.98	10.58 ± 0.69	3.40 ± 0.22
Chimpanzee....	♂	38	256—333	300 ± 1.77	16.22 ± 1.25	5.41 ± 0.42
Chimpanzee....	♀	58	249—318	286 ± 1.47	16.76 ± 1.06	5.86 ± 0.37
Orang-utan....	♂	32	229—295	269 ± 1.86	15.64 ± 1.31	5.81 ± 0.49
Orang-utan....	♀	29	216—261	234 ± 1.32	10.58 ± 0.93	4.52 ± 0.40
Siamang.....	♂ ♀	9	191—219	206 ...	....	... ...
Gibbon.....	♂ ♀	44	172—217	197 ...	....	... ...
Macaque (*rhesus*)	♂	19	131—191	170 ± 2.18	14.13 ± 1.54	8.31 ± 0.91
Macaque (*rhesus*)	♀	60	145—174	161 ± 0.58	6.66 ± 0.41	4.14 ± 0.26

to only about 5. Man, therefore, stands in regard to sex difference in size between the macaque and chimpanzee on one side and the orang-utan and gorilla on the other.

The absolute lengths of the humerus and of the femur and the degrees of their variability are listed in Tables 5 and 6. The Eskimos and the Chinese have on an average significantly shorter humeri and femora than the other human races studied. The longest humerus among all primates is found in the gorilla, particularly in the males, in which the highest individual value reaches 500 mm. Even the shortest humerus of an adult male gorilla exceeds by far the longest humerus among the human series. It is interesting to note that some siamangs and even a few gibbons have longer humeri than some adult chimpanzees. The ranges of variations in the length of the femur do not overlap in these genera.

In man and macaque the femur is always longer than the humerus. In gorilla, orang-utan, siamang, and gibbon the reversed relation exists in all cases, but in the chimpanzee the femur is equally as long as, or longer than, the humerus in 30 out of 96 skeletons, i.e. in 31 per cent of the cases. The difference in favor of the femur can be as much as 15 mm. and amounts to 14 mm. in three of the chimpanzees measured. According to Schlosser (1901) *Dryopithecus* also has a femur surpassing the humerus in length (at least in one case).

THE CLAVICULO-HUMERAL INDEX

The relation in length between the clavicle and the humerus expresses quite approximately half the width between the shoulders in percentage of the length of the upper arm. This proportion, introduced by Broca, has been utilized by many investigators in the study of racial differences in man. The averages and the conditions of variability of this index in the series of the present study are listed in Table 7. The Negroes and whites have on an average lower indices than the Eskimos, Indians and Chinese. According to their small series, the Australians possess by far the lowest claviculo-humeral index among the human races in Table 7. In the whites, Negroes, Eskimos, and Indians the averages for the males surpass those for the females. A corresponding sex difference exists in the gorilla, orang-utan and macaque. Only in the chimpanzee are the two sexes equal in regard to this proportion. In series of 50 adult male and 50 adult female American Negro skeletons Terry (1932) obtained the following averages for the claviculo-humeral index (left

TABLE 7

The claviculo-humeral index (length of clavicle in percentage of length of humerus) of adult primates

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White.....	♂	122	41.4 — 54.6	47.6 ± 0.13	2.19 ± 0.09	4.60 ± 0.20
White.....	♀	110	41.8 — 52.9	46.8 ± 0.16	2.52 ± 0.11	5.38 ± 0.24
Negro	♂	122	41.8 — 54.7	47.0 ± 0.15	2.43 ± 0.10	5.17 ± 0.22
Negro	♀	111	39.9 — 52.2	46.3 ± 0.16	2.49 ± 0.11	5.38 ± 0.24
Eskimo	♂	73	42.8 — 58.2	49.1 ± 0.22	2.76 ± 0.15	5.62 ± 0.31
Eskimo	♀	49	43.8 — 54.6	48.5 ± 0.24	2.50 ± 0.17	5.15 ± 0.35
Indian	♂	64	42.3 — 53.2	49.0 ± 0.18	2.10 ± 0.13	4.29 ± 0.26
Indian	♀	54	41.9 — 53.4	47.8 ± 0.20	2.18 ± 0.14	4.56 ± 0.30
Chinese.....	♂	39	44.6 — 55.2	48.2 ± 0.25	2.35 ± 0.18	4.88 ± 0.37
Australian	♂ ♀	7	39.4 — 45.5	43.0 ...	... ...	... ...
Gorilla (*gorilla*)	♂	68	32.2 — 41.8	37.7 ± 0.18	2.16 ± 0.13	5.73 ± 0.33
Gorilla (*gorilla*)	♀	45	31.5 — 39.8	35.8 ± 0.21	2.06 ± 0.15	5.75 ± 0.41
Chimpanzee ...	♂	35	36.2 — 45.9	42.0 ± 0.29	2.58 ± 0.21	6.14 ± 0.49
Chimpanzee ...	♀	52	36.7 — 48.3	42.2 ± 0.25	2.73 ± 0.18	6.47 ± 0.43
Orang-utan ...	♂	26	42.8 — 56.9	50.2 ± 0.51	3.83 ± 0.36	7.63 ± 0.71
Orang-utan ...	♀	30	43.6 — 52.5	47.4 ± 0.26	2.09 ± 0.18	4.41 ± 0.38
Siamang	♂ ♀	4	37.0 — 44.5	40.0 ...	... ...	... ...
Gibbon	♂ ♀	22	34.5 — 44.6	38.6 ...	... ...	... ...
Macaque (*rhesus*)	♂	19	32.6 — 43.8	39.5 ± 0.45	2.93 ± 0.32	7.42 ± 0.81
Macaque (*rhesus*)	♀	60	33.8 — 41.2	36.7 ± 0.18	2.03 ± 0.13	5.53 ± 0.34

side) : males = 46.96 ± 0.29, females = 44.76 ± 0.34. These values, which agree quite closely with those of the writer, also show that the index is larger in males than in females.

The highest average claviculo-humeral index is found in the orang-utan, which possesses not only a very long humerus, but also an exceptionally lengthened clavicle. In all the other apes and monkeys in Table 7 this index averages considerably less than in the human races. The latter stand in regard to this character between the orang-utan and the other anthropoid apes.

The new and much more extensive series of lowland gorillas confirm the author's (1934) previous finding that *Gorilla gorilla* is char-

acterized by a significantly lower claviculo-humeral index than the mountain gorilla (*G. beringei*). In the former this index averages 37.7 in males and 35.8 in females, whereas in the latter 43.6 in (4) males and 42.8 in (3) females. This difference is due to the comparatively short arm of the mountain gorilla.

THE INTERMEMBRAL INDEX

The percentage relation between the added lengths of humerus and radius and of femur and tibia is the important intermembral index on the skeleton. The present data for this index are listed in Table 8. Among the human races the whites and Negroes have for the same sex slightly lower averages than the Eskimos, Indians and Chinese. The enormous literature on this index in different races will not be reviewed here, since the data of this study are to serve chiefly for comparisons between man and other primates. It must be mentioned, however, that in all the human races measured by the author the average indices of the males lie above the corresponding averages of the females, indicating that the former possess the proportionately longer arms. From the distribution of the male and the female variations, shown by Fig. 2, it is evident that one is dealing here with an unquestionable secondary sex difference. In the chimpanzee, which is the only primate besides man with a similar sex difference, the variations above the average are not always more frequent in males than in females, as they are in whites, Negroes and Eskimos.

The maximum intermembral index among the adult human skeletons equals 79.2, the minimum value in any skeleton of the other primates examined amounts to 83.0 and belongs to a macaque. According to the data in Table 8 and the diagrams in Fig. 3, the macaques bridge the gap between the intermembral indices of man on one side and those of the anthropoid apes on the other side. Among the latter there is not a single case with an intermembral index below 100 (minimum value = 100.1). The indices of the anthropoid apes form one uninterrupted series from 100 to 155 and there are always some generic ranges of variations which overlap extensively. Thus, one can not distinguish by the intermembral index alone between gorillas and chimpanzees. One can, however, tell gibbons and siamangs apart by merely knowing their intermembral proportions. That the intermembral indices of at least

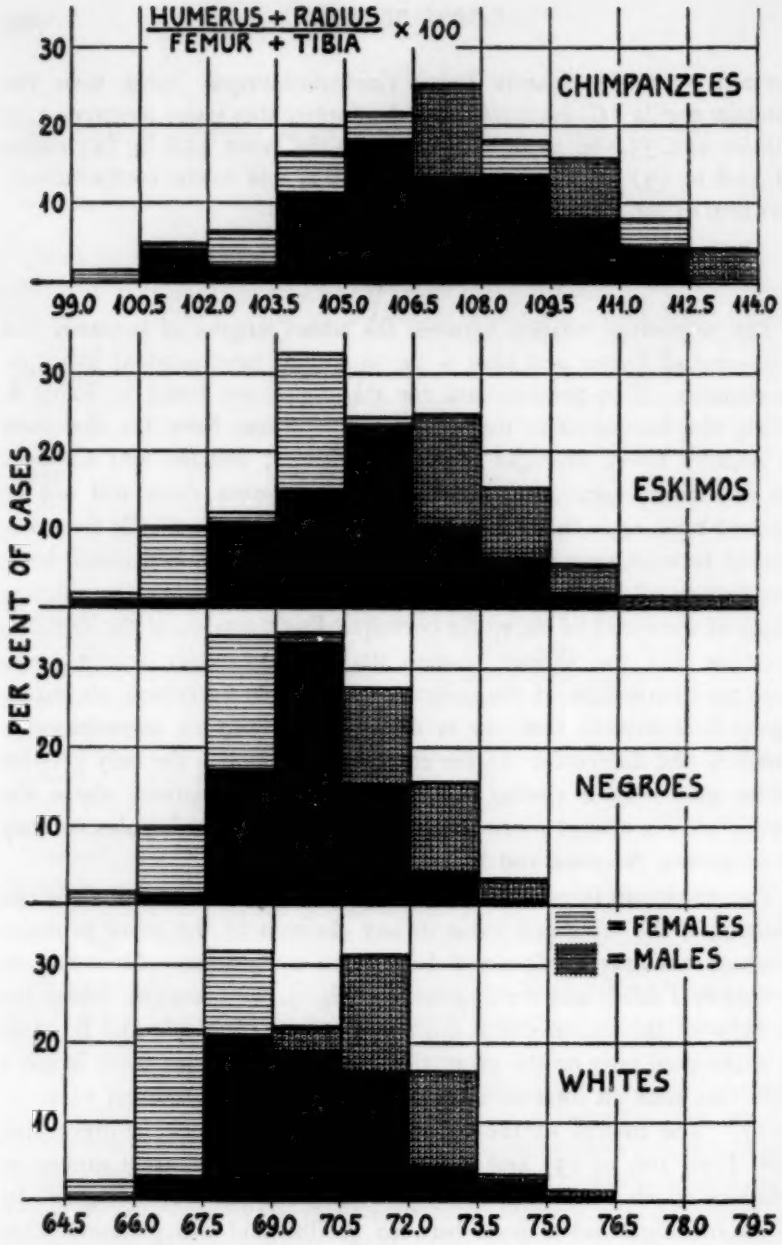

FIG. 2. FREQUENCY POLYGONS SHOWING THE PERCENTAGE DISTRIBUTION OF VARIATIONS OF THE INTERMEMBRAL INDEX IN THE TWO SEXES OF ADULT CHIMPANZEES, ESKIMOS, NEGROES, AND WHITES

The black areas represent the zones of overlapping of the polygons for males and for females. The variations are divided into groups representing 1.4 index units each.

the siamangs and orang-utans have in all probability undergone a more far-reaching phylogenetic change in one direction than have those of man in the opposite direction, has already been discussed by the author (1930 and 1933) in other papers.

TABLE 8

The intermembral index (length of humerus + radius in percentage of length of femur + tibia) of adult primates

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White	♂	122	65.3— 75.7	70.5±0.12	1.89±0.08	2.68±0.12
White	♀	110	64.5— 74.4	69.0±0.13	2.05±0.09	2.97±0.13
Negro	♂	122	66.5— 74.5	70.3±0.10	1.62±0.07	2.30±0.10
Negro	♀	111	65.6— 73.6	69.2±0.10	1.62±0.07	2.34±0.11
Eskimo	♂	73	65.9— 78.0	71.7±0.19	2.41±0.13	3.36±0.19
Eskimo	♀	49	64.9— 75.0	70.2±0.20	2.13±0.14	3.03±0.21
Indian	♂	64	67.3— 75.5	71.5±0.14	1.67±0.10	2.34±0.14
Indian	♀	54	68.9— 79.2	71.3±0.15	1.65±0.11	2.31±0.15
Chinese	♂	39	67.1— 74.0	71.1±0.18	1.70±0.13	2.39±0.18
Australian	♂ ♀	7	68.0— 72.0	70.2 ...	... ...	... ...
Gorilla (*gorilla*)	♂	93	110.3—123.4	116.5±0.19	2.70±0.13	2.32±0.11
Gorilla (*gorilla*)	♀	60	110.8—125.0	117.8±0.26	3.01±0.19	2.56±0.16
Chimpanzee	♂	44	100.5—113.7	107.3±0.29	2.83±0.20	2.64±0.19
Chimpanzee	♀	60	100.1—112.0	106.4±0.25	2.83±0.18	2.66±0.16
Orang-utan	♂	41	135.0—149.9	142.8±0.41	3.88±0.29	2.72±0.20
Orang-utan	♀	38	139.2—150.9	144.9±0.36	3.26±0.25	2.25±0.17
Siamang	♂ ♀	19	145.0—155.2	148.5 ...	... ...	... ...
Gibbon.....	♂ ♀	50	120.5—137.1	128.3 ...	... ...	... ...
Macaque (*rhesus*)	♂	19	84.8— 90.2	87.4±0.25	1.60±0.17	1.83±0.20
Macaque (*rhesus*)	♀	60	83.0— 91.0	87.6±0.14	1.62±0.10	1.85±0.11

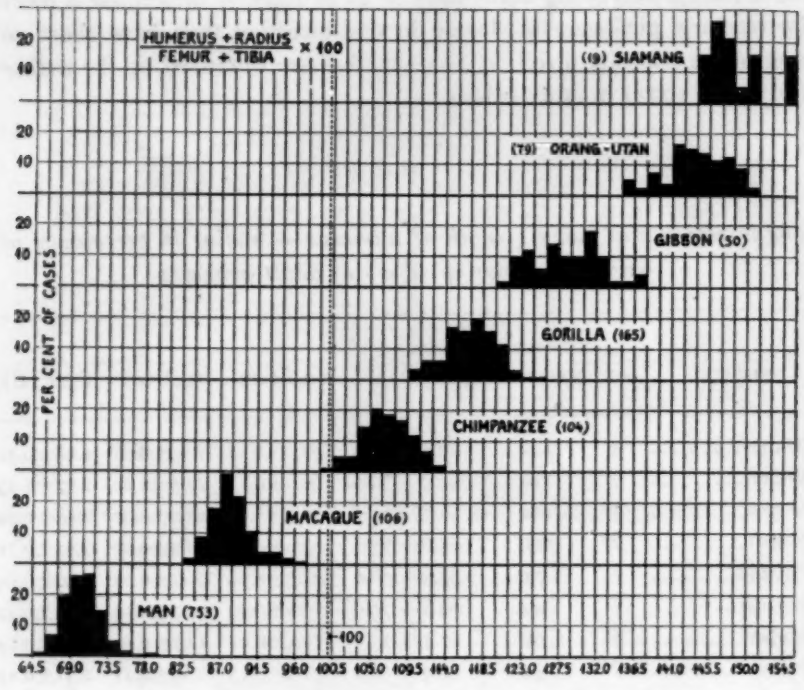

FIG. 3. FREQUENCY POLYGONS SHOWING THE PERCENTAGE DISTRIBUTION OF VARIATIONS OF THE INTERMEMBRAL INDEX IN THE ENTIRE MATERIAL STUDIED, ACCORDING TO THE DIFFERENT MAJOR TYPES OF PRIMATES

The variations are divided into groups representing 1.4 index units each. The figures in parentheses give the total numbers of skeletons used for each series.

THE BRACHIAL INDEX

The data for the brachial index, or the percentage relation between the lengths of the radius and the humerus, are listed in Table 9. Among the human races this index is significantly lower in whites and Eskimos than in Negroes, Indians, Chinese, and Australians. In all the races for which sufficient series of both sexes could be measured the averages of the males are higher than the corresponding averages of the females (see also Fig. 4). Males, therefore, are characterized by a proportionately long radius. With the exception of the orang-utan the apes and

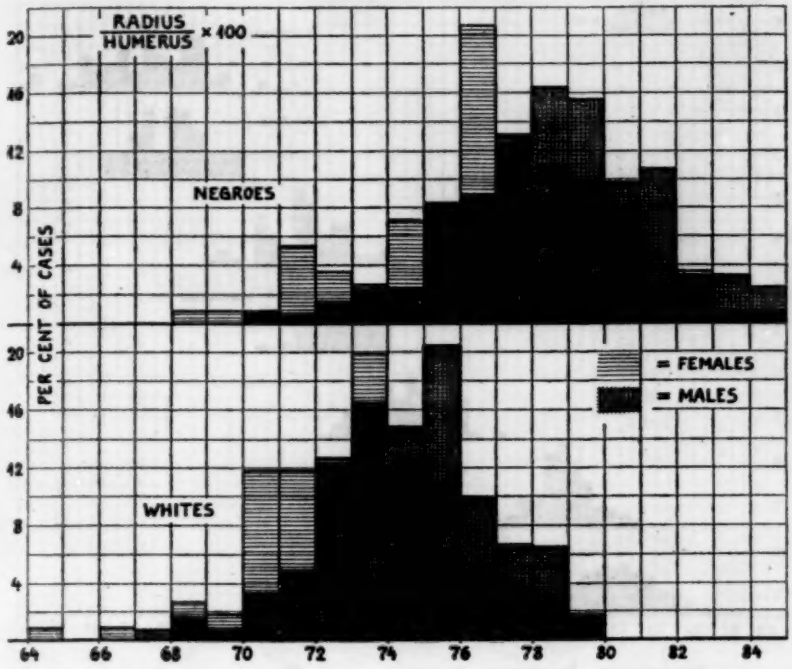

FIG. 4. FREQUENCY POLYGONS SHOWING THE PERCENTAGE DISTRIBUTION OF VARIATIONS OF THE BRACHIAL INDEX IN THE TWO SEXES OF ADULT WHITES AND NEGROES

The variations are divided into groups representing 0.9 index units each.

monkeys also show higher average brachial indices in males than in females, but in no case is this sex difference as pronounced as in man.

Among the adult primates studied the brachial index varies between 64.9 and 123.9. As shown clearly by Fig. 5, the ranges of variations of the different types of primates overlap extensively and there is no type which is really separated from all other types. On a general average man has the proportionately shortest forearm among all these primates, but over half of the individual values in man fall in the range of variations in the gorillas. Among the latter the mountain gorilla has a higher brachial index (average of 7 specimens = 84.8) than the lowland gorilla (see Table 9 and Schultz, 1934). Even the range of

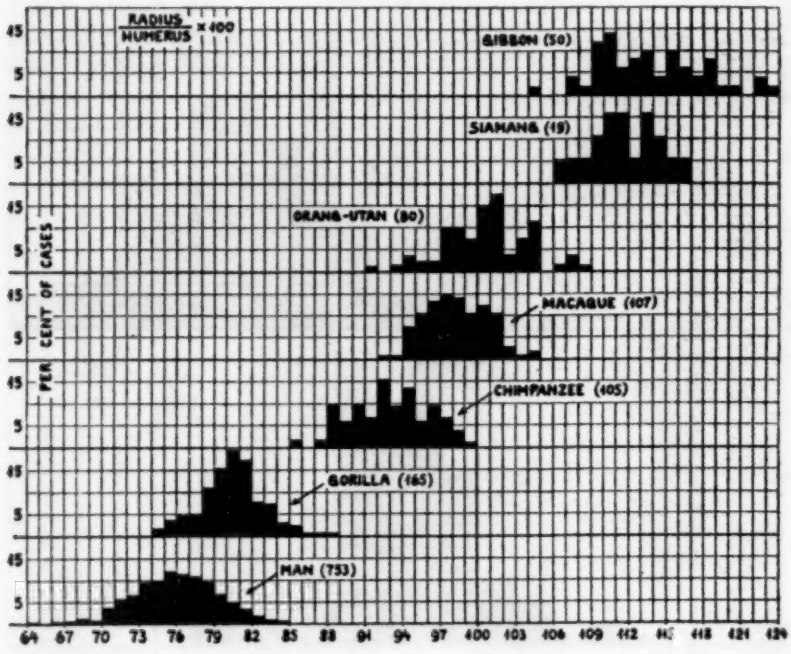
RADIUS / HUMERUS × 100
PER CENT OF CASES
GIBBON (50)
SIAMANG (19)
ORANG-UTAN (80)
MACAQUE (107)
CHIMPANZEE (105)
GORILLA (165)
MAN (753)
64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124

FIG. 5. FREQUENCY POLYGONS SHOWING THE PERCENTAGE DISTRIBUTION OF VARIATIONS OF THE BRACHIAL INDEX IN THE ENTIRE MATERIAL STUDIED, ACCORDING TO THE DIFFERENT MAJOR TYPES OF PRIMATES

The variations are divided into groups representing 0.9 index units each. The figures in parentheses give the total numbers of skeletons used for each series.

variations in chimpanzees reaches the range among human groups. Thus, the minimum value of the former (85.6) is surpassed by at least some Annamese for whom an average value of 86.7 is quoted by Martin (1928) in a list of brachial indices in many human races.

THE CRURAL INDEX

The averages and the conditions of variability of the percentage relation in length between tibia and femur, or the so-called crural index, are shown in Table 10. This index is much more uniform among the primates studied than are the previous two proportions. The crural index fluctuates only between 73.9 in a gorilla and 99.1 in an orang-utan.

TABLE 9

The brachial index (length of radius in percentage of length of humerus) of adult primates

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White	♂	122	67.2— 79.1	74.5±0.14	2.29±0.10	3.07±0.13
White	♀	110	64.9— 79.3	73.2±0.16	2.57±0.12	3.51±0.16
Negro	♂	122	70.2— 84.6	78.5±0.17	2.73±0.12	3.48±0.15
Negro	♀	111	68.1— 84.1	77.0±0.19	3.04±0.14	3.95±0.18
Eskimo	♂	73	67.0— 82.1	74.7±0.21	2.64±0.15	3.53±0.20
Eskimo	♀	49	66.4— 79.0	72.7±0.24	2.52±0.17	3.47±0.24
Indian	♂	64	71.6— 83.7	78.2±0.22	2.58±0.15	3.30±0.20
Indian	♀	54	71.1— 82.9	76.9±0.22	2.38±0.15	3.09±0.20
Chinese	♂	39	72.5— 82.0	77.3±0.23	2.11±0.16	2.73±0.21
Australian	♂ ♀	7	76.0— 80.7	78.3 ...	... ...	... ...
Gorilla (*gorilla*)	♂	93	74.5— 85.2	80.4±0.15	2.16±0.11	2.69±0.13
Gorilla (*gorilla*)	♀	60	74.3— 86.2	79.9±0.20	2.29±0.14	2.87±0.18
Chimpanzee	♂	45	87.0— 99.7	93.1±0.32	3.21±0.23	3.45±0.24
Chimpanzee	♀	60	85.6— 98.9	92.6±0.26	2.98±0.18	3.22±0.20
Orang-utan	♂	41	91.7—108.5	100.3±0.39	3.73±0.28	3.72±0.28
Orang-utan	♀	39	94.0—107.5	100.7±0.33	3.04±0.23	3.02±0.23
Siamang	♂ ♀	19	106.0—116.0	111.4 ...	... ...	... ...
Gibbon	♂ ♀	50	104.8—123.9	113.5 ...	... ...	... ...
Macaque (*rhesus*)	♂	19	94.3—102.2	98.5±0.34	2.19±0.24	2.22±0.24
Macaque (*rhesus*)	♀	60	92.7—101.7	97.6±0.19	2.22±0.14	2.27±0.14

Among the human races this proportion is on an average the highest in Australians and the lowest in Eskimos, whites and Chinese. In the gorilla the crural index is even considerably lower than in the last mentioned human races, i.e. gorillas have a proportionately shorter tibia than have the various human races. In previous and not yet published investigations on the relative position of certain muscle insertions in dissecting room material the author had measured the length of femur and of tibia. From these additional data the following crural indices were obtained: average of 62 adult (♂ and ♀) whites = 84.0 and average of 76 adult (♂ and ♀) American Negroes = 85.9. These

TABLE 10

The crural index (length of tibia in percentage of length of femur) of adult primates

PRIMATE	SEX	NUMBER OF SKELETONS	RANGE OF VARIATIONS	$A \pm E(A)$	$\sigma \pm E(\sigma)$	$C \pm E(C)$
White	♂	122	78.1 — 90.0	83.3 ± 0.13	2.12 ± 0.09	2.55 ± 0.11
White	♀	110	77.8 — 89.3	83.5 ± 0.15	2.37 ± 0.11	2.84 ± 0.13
Negro	♂	122	80.0 — 91.1	86.2 ± 0.16	2.59 ± 0.11	3.00 ± 0.13
Negro	♀	111	80.5 — 92.4	86.1 ± 0.15	2.38 ± 0.11	2.76 ± 0.12
Eskimo	♂	73	76.0 — 90.1	83.0 ± 0.22	2.80 ± 0.16	3.37 ± 0.19
Eskimo	♀	49	77.4 — 86.8	82.3 ± 0.24	2.48 ± 0.17	3.01 ± 0.20
Indian	♂	64	80.2 — 92.4	85.9 ± 0.20	2.39 ± 0.14	2.78 ± 0.17
Indian	♀	54	80.3 — 89.8	85.2 ± 0.20	2.18 ± 0.14	2.56 ± 0.17
Chinese	♂	39	80.6 — 88.7	83.6 ± 0.20	1.82 ± 0.14	2.18 ± 0.17
Australian	♂ ♀	7	84.8 — 92.6	88.8 ...	... ...	... ...
Gorilla (*gorilla*)	♂	93	73.9 — 85.8	79.9 ± 0.15	2.20 ± 0.11	2.75 ± 0.13
Gorilla (*gorilla*)	♀	60	77.4 — 85.2	80.8 ± 0.19	2.18 ± 0.13	2.70 ± 0.17
Chimpanzee	♂	44	79.2 — 88.8	83.5 ± 0.23	2.25 ± 0.16	2.69 ± 0.19
Chimpanzee	♀	60	77.9 — 87.8	83.4 ± 0.20	2.35 ± 0.15	2.82 ± 0.17
Orang-utan	♂	41	83.8 — 97.2	91.5 ± 0.33	3.11 ± 0.23	3.40 ± 0.25
Orang-utan	♀	38	85.9 — 99.1	92.3 ± 0.32	2.98 ± 0.23	3.23 ± 0.25
Siamang	♂ ♀	19	83.0 — 90.0	86.0 ...	... ...	... ...
Gibbon	♂ ♀	50	85.0 — 94.0	88.7 ...	... ...	... ...
Macaque (*rhesus*)	♂	19	88.6 — 98.2	91.9 ± 0.43	2.79 ± 0.30	3.04 ± 0.33
Macaque (*rhesus*)	♀	60	88.5 — 96.1	92.0 ± 0.15	1.70 ± 0.11	3.14 ± 0.19

values agree quite closely with the new corresponding figures, based upon much larger series, in Table 10.

In contrast to the intermembral index and the brachial index, the crural index does not differ significantly in the two sexes.

VARIABILITY

For the sake of condensed and convenient comparisons between the conditions of variability in the major groups of primates and in the different characters studied arithmetic means have been calculated of the variation coefficients in the Tables 5 to 10.

TABLE 11

Arithmetic means of the variation coefficients of the absolute lengths and proportions in man, the great apes and the macaque (rhesus monkey), based upon the detailed data in Tables 5, 6, 7, 8, 9, and 10

AVERAGE $C \pm E(C)$	MAN	GREAT APES	MACAQUE
Humerus length	4.89 ± 0.27	5.10 ± 0.33	5.56 ± 0.51
Femur length	5.10 ± 0.28	4.93 ± 0.26	6.22 ± 0.58
Clavicule-humeral I.	5.00 ± 0.28	6.02 ± 0.46	6.47 ± 0.57
Intermembral index	2.64 ± 0.15	2.52 ± 0.16	1.84 ± 0.15
Brachial index	3.35 ± 0.19	3.16 ± 0.21	2.24 ± 0.19
Crural index	2.78 ± 0.15	2.93 ± 0.19	3.09 ± 0.26

According to Table 11 the average variation coefficients of the humerus length and of the femur length do not differ significantly either in man, or the great apes, or the macaque. Among the proportions the claviculo-humeral index is by far the most variable one in all three of these types of primates. The intermembral index has the lowest average variation coefficient of all the indices not only in man, but also in the great apes and the macaque. The intermembral index is remarkable for its low variability not only when based upon skeletal dimensions, but also when derived from measurements on the outer body. Thus, the author (1926) obtained lower variation coefficients for the intermembral index than for 13 other proportions of the outer body in series of adult as well as of fetal human bodies. According to Table 11 the brachial index is more variable than the crural index in man, whereas in the great apes there exists no significant difference between these two indices and in the macaque the crural index is more variable than the brachial index.

That some proportions, such as the claviculo-humeral index, can be much more variable than others, such as the intermembral index, and this consistently in widely different types of primates, is evident also from the previous finding of the author (1926) that spider monkeys as well as howler monkeys have very much higher variation coefficients for the measurements and proportions of the face part of the skull than for those appertaining to the brain part. In comparing the degrees of variability in different groups of primates one can, therefore, utilize only strictly corresponding characters.

TABLE 12

Arithmetic means of the variation coefficients of humerus length, femur length, clavicular-humeral index, intermembral index, brachial index, and crural index, as listed in Tables 5, 6, 7, 8, 9, and 10

PRIMATE	AVERAGE $C \pm E(C)$	PRIMATE	AVERAGE $C \pm E(C)$
White ♂	3.77 ± 0.16	Gorilla ♂	3.84 ± 0.20
White ♀	4.30 ± 0.19	Gorilla ♀	3.59 ± 0.23
Negro ♂	4.06 ± 0.17	Chimpanzee ♂	4.33 ± 0.32
Negro ♀	4.18 ± 0.19	Chimpanzee ♀	4.58 ± 0.29
Eskimo ♂	4.29 ± 0.24	Orang-utan ♂	4.74 ± 0.38
Eskimo ♀	4.07 ± 0.28	Orang-utan ♀	3.58 ± 0.29
Indian ♂	3.69 ± 0.22	*Average for great apes*	*4.11 ± 0.28*
Indian ♀	3.74 ± 0.24		
Chinese ♂	3.54 ± 0.27	Macaque ♂	5.00 ± 0.54
Average for man	*3.96 ± 0.22*	Macaque ♀	3.48 ± 0.21

Table 12 lists the arithmetic means of the variation coefficients of the two absolute lengths and the four indices in the Tables 5 to 10 for each of the different groups of primates for which there were sufficiently large series of males and of females. These averages naturally would mean nothing by themselves, but, being based upon exactly the same characters in every case, they serve as an entirely comparable expression of the relative degree of variability in each group and sex. Among the human races there exists no really significant difference in regard to variability and there is no consistent and marked difference between the two sexes. It is interesting to find that the composite series of American Indians is, if anything, slightly less variable than the supposedly homogeneous series of Alaskan Eskimos and that the latter are as variable as the whites, who are sometimes supposed to have an unusually high variability on account of extensive mixture between "sub-races" and absence of "natural selection".

In regard to the lengths and proportions discussed here the great apes have on a general average approximately the same degree of variability as have human races and the macaque is only slightly more

variable, the average of the variation coefficients of males and of females amounting to 4.24 (for the single species *Pithecus rhesus!*). The orang-utan and the macaque are the only primates among the types studied in which there is a marked sex difference in variability, in both the females being more uniform than the males.

If *Homo sapiens* as a whole and without regard to racial divisions is compared with the other primates (as is done in the Figs. 3 and 5), it is found that man as a species can exceed some of the apes in regard to the total ranges of variations of the indices studied. For the intermembral index this range extends over 14.7 index units in man, including the six races used, also over 14.7 units in the single species *Gorilla gorilla,* and over 15.9 units in orang-utan which constitutes most likely also only one species. In chimpanzee with certainly several species this range amounts to only 13.6 units and in the gibbons with at least seven species to not much more, namely 16.6 units. In the case of the brachial index the variations spread over 19.7 index units among all the human races combined, over 19.1 units in the gibbons, over 16.8 units in the orang-utan, over 14.1 units in the chimpanzee, and over only 11.9 units in the lowland gorilla. The ranges of variations of the crural index extend over 16.6 index units in man, but over only 15.3 units in the orang-utan, 11.9 in the gorilla, and 10.9 units in the chimpanzee.

It is as yet premature to generalize, but it appears that at least in regard to some skeletal dimensions and proportions single human races are approximately as variable as entire species (e.g. lowland gorilla, orang-utan, rhesus monkey) or even genera (e.g. chimpanzees of several species) of apes and that mankind as a whole can surpass some of the species and even genera of the anthropoids in this respect. This is supported also by previous observations of the author, i.e. the variation coefficients of some cranial dimensions and indices are practically the same in platyrrhine species *Alouatta palliata* and *Ateles geoffroyi* as in series of Swiss Alpines, of Bavarians, of Greenland Eskimos, and of Melanesians (Schultz, 1926). On the other hand, numerical variations in the vertebrae of various regions are very much more common in all the anthropoid apes and in some platyrrhine species than in man (Schultz, 1930). The cranial capacity varies in adult man in general and disregarding rare extreme variations between at least 1100 and 1700 cu. cm. (Martin, 1928). This range amounts to 43 per cent of the quite approximate general average of 1400 cu. cm. Hagedoorn

(1926) has collected corresponding data for large series of great apes: the range of variations in the cranial capacity of adults in percentage of the average capacity equals in 197 gorillas 62.5, in 122 chimpanzees 40.2, and in 254 orang-utans 68.0. In males alone these figures are 52.4 for gorillas, 31.7 for chimpanzees, and 57.5 for orang-utans. It appears that in this character gorilla and orang-utan are more variable than man, whereas the chimpanzee is slightly less so, unless it is assumed that a larger series of the latter would increase their relative range of variations.

It is readily seen that a great deal more work will have to be done on this subject before generally valid conclusions can be drawn and before one can throw new light on the problem whether human races are really equivalent to species in other primate genera.

FREQUENCY AND DISTRIBUTION OF ASYMMETRIES

The percentage frequency and distribution of asymmetries in the bones of the upper extremities of the human material is listed in Table 13. In Table 14 the data on asymmetries in the humerus of whites and

TABLE 13

Percentage distribution of asymmetries in the upper extremities of human races

	HUMERUS			RADIUS			HUMERUS + RADIUS		
RACE AND SEX	r.>	r.=l.	l.>	r.>	r.=l.	l.>	r.>	r.=l.	l.>
White ♂	66	11	23	72	9	19	77	4	19
White ♀	75	8	17	76	12	12	83	4	13
Negro ♂	40	10	50	63	17	20	60	4	36
Negro ♀	70	11	19	71	12	17	79	7	14
Eskimo ♂	74	9	17	53	19	28	74	6	20
Eskimo ♀	90	2	8	74	13	13	91	0	9
Indian ♂	81	3	16	66	9	25	83	5	12
Indian ♀	86	6	8	72	12	16	94	2	4
Chinese ♂ ♀	68	16	16	80	10	10	84	3	13
Australian ♂ ♀ ..	67	0	33	67	0	33	67	0	33

Negroes have been supplemented by some corresponding, previous observations of the author (1918), gained also on dissecting room bodies. These tables permit the following conclusions: in all the races studied asymmetries in the humerus and in the radius as well as in the added measurements of these two bones favor the right side much more frequently than the left. Only in the case of the humerus of the male Negroes is this rule barely noticeable (Table 14), since in this series

TABLE 14

Distribution of asymmetries in the humeri of whites and Negroes according to the combined data from the present series and from a previous investigation by the author (1918)

RACE AND SEX	SOURCE	TOTAL	r.>	r.=l.	l.>
White ♂	present series	122	81	13	28
White ♂	1918	40	17	10	13
White ♂ Combined		162	98	23	41
Percentage.....			**61**	**14**	**25**
White ♀	present series	110	83	9	18
White ♀	1918	11	9	0	2
White ♀ Combined		121	92	9	20
Percentage.....			**76**	**7**	**17**
Negro ♂	present series	121	49	12	60
Negro ♂	1918	38	22	8	8
Negro ♂ Combined		159	71	20	68
Percentage.....			**45**	**12**	**43**
Negro ♀	present series	109	76	12	21
Negro ♀	1918	16	9	7	0
Negro ♀ Combined		125	85	19	21
Percentage.....			**68**	**15**	**17**

of 159 skeletons the left humeri are longer than the right ones in 43 per cent of the cases. Symmetry is considerably rarer in the lengths of humerus + radius than in the lengths of the single bones alone—a result that might have been expected. Asymmetries in favor of the right side are more common in the former than in the latter measurements. In white males of the present series the length of humerus + radius is longer on the right than on the left in 77 per cent of the cases. This agrees very closely with the finding by Hasse and Dehner (1893) that among 5141 German soldiers the right arm surpassed the left in length in 75 per cent of the cases. It does not agree, however, with the results of Rollet (1902), who found the humerus + radius longer on the right than on the left side in 98 per cent of 50 male and in 94 per cent of 50 female European skeletons, and the reversed relation in only 3 out of these hundred skeletons!

From Tables 13 and 14 it is evident that asymmetries in favor of the right side are consistently more frequent in females than in males among whites, Negroes, Eskimos, and Indians and this in the humerus as well as the radius and the combined length of the two bones. In regard to racial differences it can merely be tentatively stated that in the upper extremity asymmetries favoring the right bones are rarest in male Negroes and most common in female Indians and Eskimos. Even the primitive Australian aboriginals fall between these extremes. The writer's small series of data for this race can be supplemented by some observations by Breitbart, tabulated by Mollison (1911). These combined series of Australians result in the following percentage frequencies of asymmetries: Humerus (14 skeletons) r. > 71; r. = l. 0; l. > 29: Radius (12 skeletons) r. > 67; r. = l. 8; l.> 25: Femur (12 skeletons) r. > 25; r. = l. 33; l. > 42: Tibia (9 skeletons) r. > 45; r. = l. 22; l. > 33.

It may here be mentioned that in a series of 100 white fetuses the author (1926) found the right humerus longer than the left in 52 per cent of the cases, the reversed relation in 21 per cent of the cases, and symmetry (measuring to one tenth of a millimeter) in the remaining 27 per cent of the cases. Even in early development, therefore, human asymmetries of the upper extremities are more frequently in favor of the right than the left side.

The percentage frequencies and distribution of asymmetries of the lower extremities among the human races studied are listed in Table 15. Again it is possible to give some supplementary data for whites

TABLE 15

Percentage distribution of asymmetries in the lower extremities of human races

RACE AND SEX	FEMUR			TIBIA			FEMUR + TIBIA		
	r.>	r.=l.	l.>	r.>	r.=l.	l.>	r.>	r.=l.	l.>
White ♂	28	20	52	47	12	41	38	9	53
White ♀	31	24	45	41	12	47	39	3	58
Negro ♂	35	12	53	45	16	39	43	3	54
Negro ♀	36	15	49	37	19	44	40	6	54
Eskimo ♂	33	15	52	33	12	55	42	7	51
Eskimo ♀	41	14	45	39	20	41	47	10	43
Indian ♂	27	20	53	40	20	40	40	2	58
Indian ♀	42	13	45	39	14	47	46	8	46
Chinese ♂ ♀	34	10	56	32	7	61	32	12	56
Australian ♂ ♀ ..	17	33	50	25	0	75	25	0	75

and Negroes (Table 16), derived from former observations by the author made in the course of studies on the relative position of certain muscle insertions in dissecting room material. In the lower extremities asymmetries favor more frequently the left than the right side in all the groups and both sexes, with the exception of the tibia of male Negroes (Table 16). This preponderance of one side is not nearly as marked in the lower extremities (in favor of the left) as it is in the upper extremities (in favor of the right).

A consistent sex difference in the frequency with which one side is favored by asymmetries of the lower extremities exists only in regard to the femur, since it is shown by Table 15 that the left femur surpasses the right in length more frequently in males than in females in whites, Negroes, Eskimos, and Indians. The various races are remarkably similar in regard to the distribution of the asymmetries in the lower extremities, if one disregards the small series of Australians. The length of femur + tibia is longer on the left in 53 per cent of male

TABLE 16

Distribution of asymmetries in the femora and tibiae of whites and Negroes according to the combined data from the present series and from an as yet unpublished, previous investigation by the author

RACE AND SEX	SOURCE	FEMUR				TIBIA			
		Total	r.>	r.=l.	l.>	Total	r.>	r.=l.	l.>
White ♂	present series	121	34	24	63	118	56	14	48
White ♂	previous series	41	13	6	22	41	12	1	28
White ♂	*Combined*	162	47	30	85	159	68	15	76
	Percentage		**29**	**19**	**52**		**43**	**9**	**48**
White ♀	present series	110	34	26	50	110	45	13	52
White ♀	previous series	9	2	2	5	9	4	3	2
White ♂	*Combined*	119	36	28	55	119	49	16	54
	Percentage		**30**	**24**	**46**		**41**	**14**	**45**
Negro ♂	present series	122	43	14	65	121	54	20	47
Negro ♂	previous series	36	19	5	12	36	13	6	17
Negro ♂	*Combined*	158	62	19	77	157	67	26	64
	Percentage		**39**	**12**	**49**		**43**	**16**	**41**
Negro ♀	present series	111	40	17	54	109	40	21	48
Negro ♀	previous series	17	7	0	10	17	5	1	11
Negro ♀	*Combined*	128	47	17	64	126	45	22	59
	Percentage		**37**	**13**	**50**		**36**	**17**	**47**

whites. This is practically identical with the finding by Hasse and Dehner (1893) that among 5141 German soldiers the left leg surpassed the right in length in 52 per cent of the cases. The writer's results agree also very closely with those of Garson (1879), who records that in 70 skeletons the femur + tibia was longer on the left in 54.3 per cent and longer on the right in 35.8 per cent of the cases. In a series of 124 Allamannic skeletons from Switzerland Schwerz (1912) found the left femur to be longer in 52 per cent of the cases and the right femur to be longer in 31 per cent. For the tibia his results agree less closely with those of the writer since the left tibia was longer in 63 per cent and the right longer in only 26 per cent of 115 Allamannic skeletons.

The percentage distribution of asymmetries in the lengths of the clavicles in different human races is shown in Table 17. In all the racial groups (except the few Australians) and in both sexes asymmetries favoring the left bone are much more frequent than those favoring the right bone. This contrast is particularly striking in Eskimos and

TABLE 17

Percentage distribution of asymmetries in the clavicles of human races

RACE AND SEX	CLAVICLE		
	r.>	r.=l.	l.>
White ♂	27	15	58
White ♀	28	13	59
Negro ♂	25	15	60
Negro ♀	30	15	55
Eskimo ♂	12	14	74
Eskimo ♀	13	13	74
Indian ♂	27	10	63
Indian ♀	26	20	54
Chinese ♂ ♀	17	3	80
Australian ♂ ♀	57	0	43

Chinese. That the left clavicle surpasses the right in length is the general rule in man according to the authors quoted by Martin (1928). Terry (1932) also obtained larger averages for the length of the left than for that of the right clavicle in male and female Negroes and in male whites. These results are rather surprising in view of the fact that it is the right half of the thorax which is the larger (Gaupp, 1909 and others), and that the right arm is usually the longer and stronger one.

The occurrence and distribution of asymmetries in the limb bones of adult anthropoid apes has been reported by several authors[4] whose data are included in Table 18. The combined data, available so far for comparisons between man and other primates, are listed in Tables 19 to 25 and are shown diagrammatically in Fig. 6. Since no significant sex difference in the distribution of asymmetries could be found in any of the apes or in the macaque, the two sexes have been combined in all these tables. For these general comparisons racial differences in man have been disregarded and the entire material of human skeletons has been dealt with as only one series. Similarly, all the species of the family Hylobatidae and of the genus *Pithecus* and of the genus *Gorilla* have been combined into single series each.

From Tables 19 to 25 as well as from Fig. 6 it is evident first of all that, in general, cases of symmetry are rarer in man than in the other primates. The humeri, e.g. are symmetrical in only 9 per cent of the cases in man, whereas in 13 to 16 per cent in the great apes, in 22 per cent in Hylobatidae, and in 29 per cent in macaques.

The bones of the upper extremities are most commonly longer on the right in man, as has been demonstrated above. In none of the other primates is there anywhere near such a preponderance of asymmetries favoring one side, as exists in man. The bones of the left arm are somewhat more frequently the longer ones than those of the right arm in gorillas and in chimpanzees. The differences between the frequencies

[4] As stated by Gaupp (1909), Rollet (whose paper the writer was unable to examine) found in a series of "42 anthropoids" the right humerus longer in 5 cases, the left longer in 27 cases, and both humeri equally long in 10 cases. Unfortunately it was impossible to learn the genera and the ages of these anthropoids. Guldberg (1897) examined the skeletons of 4 orang-utans and 1 gibbon for asymmetries and merely states that among the former the right side predominated in 2 cases, the left in 1 case, and in the fourth case the left upper and the right lower extremity were the longer ones; in the gibbon the asymmetries favored the right extremities.

TABLE 18

The total numbers of skeletons of anthropoid apes for which the asymmetries of the long bones of the limbs have been reported by different authors and the distribution (absolute values) of these asymmetries

(The percentage distribution of the totals is given in the Tables 19, 20, 22, and 23.)

PRIMATE	AUTHOR	YEAR	HUMERUS				RADIUS				FEMUR				TIBIA			
			Total	r.>	r.=l.	l.>	Total	r.>	r.=l.	l.>	Total	r.>	r.=l.	l.>	Total	r.>	r.=l.	l.>
Gorilla	Manouvrier	1882	..	..	..	..	..	..	..	..	6	2	1	3	..	..	..	..
	Bardeleben	1909	6	1	0	5	1	1	0	0	3	0	1	2	2	0	2	0
	Mollison	1911	15	7	3	5	16	4	7	5	16	6	3	7	17	2	5	10
	Schultz	1937	127	46	20	61	130	47	20	63	135	61	26	48	128	56	25	47
Chimpanzee	Bardeleben	1909	8	2	1	5	3	1	1	1	8	1	..	7	2	..	1	1
	Mollison	1911	11	4	3	4	12	2	5	5	12	3	2	7	10	5	2	3
	Schultz	1937	82	31	11	40	83	25	18	40	79	30	17	32	84	32	20	32
Orang-utan	Bardeleben	1909	8	7	1	0	..	..	..	..	6	5	..	1	1	0	1	0
	Mollison	1911	14	7	4	3	19	13	1	5	17	6	6	5	17	6	7	4
	Schultz	1937	48	27	4	17	51	27	5	19	49	22	12	15	49	19	7	23
Hylobatidae	Mollison	1911	20	10	3	7	18	14	2	2	20	7	7	6	20	7	9	4
	Schultz	1937	21	9	6	6	25	8	2	15	22	11	3	8	23	8	3	12

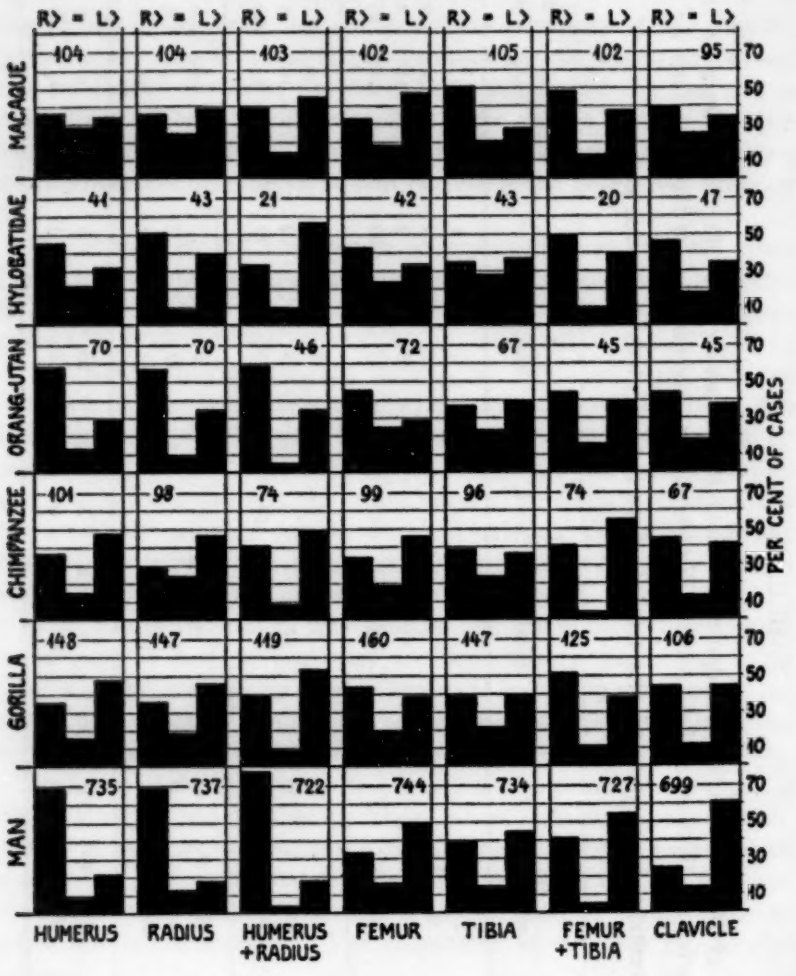

FIG. 6. DIAGRAMMATIC REPRESENTATION OF THE PERCENTAGE FREQUENCIES OF ASYMMETRIES IN THE LIMB BONES AND CLAVICLES IN THE ENTIRE MATERIAL OF ADULT PRIMATES LISTED IN TABLES 19, 20, 21, 22, 23, 24, and 25

The black columns underneath "R>" represent the relative numbers of the cases in which the right bone surpassed the left one in length. In the same way "L>" indicates asymmetries in favor of the left side. Symmetry is marked by an = sign. The figures above each diagram show the numbers of skeletons used for the construction of the particular frequency polygon.

TABLE 19

Percentage distribution of asymmetries in the humerus of adult primates

(The values for the anthropoid apes include the data from the literature, listed in Table 18.)

PRIMATE (both sexes)	HUMERUS			
	Total	r.>	r.=l.	l.>
Man (all races).....	735	69	9	22
Gorilla (all species)	148	36	16	48
Chimpanzee	101	37	15	48
Orang-utan.....	70	58	13	29
Hylobatidae (all species).....	41	46	22	32
Macaque (all species).....	104	37	29	34

TABLE 20

Percentage distribution of asymmetries in the radius of adult primates

(The values for the anthropoid apes include the data from the literature, listed in Table 18.)

PRIMATE (both sexes)	RADIUS			
	Total	r.>	r.=l.	l.>
Man (all races).....	737	69	13	18
Gorilla (all species).....	147	36	18	46
Chimpanzee	98	29	24	47
Orang-utan	70	57	9	34
Hylobatidae (all species).....	43	51	9	40
Macaque (all species).....	104	36	25	39

TABLE 21

Percentage distribution of asymmetries in the combined length of humerus and radius of adult primates

PRIMATE (both sexes)	HUMERUS + RADIUS			
	Total	r.>	r.=l.	l.>
Man (all races)	722	78	4	18
Gorilla (all species)	119	39	8	53
Chimpanzee	74	41	9	50
Orang-utan	46	59	6	35
Hylobatidae (all species)	21	33	10	57
Macaque (all species)	103	40	15	45

TABLE 22

Percentage distribution of asymmetries in the femur of adult primates

(The values for the anthropoid apes include the data from the literature, listed in Table 18.)

PRIMATE (both sexes)	FEMUR			
	Total	r.>	r.=l.	l.>
Man (all races)	744	33	17	50
Gorilla (all species)	160	43	19	38
Chimpanzee	99	34	19	47
Orang-utan	72	46	25	29
Hylobatidae (all species)	42	43	24	33
Macaque (all species)	102	33	19	48

TABLE 23

Percentage distribution of asymmetries in the tibia of adult primates

(The values for the anthropoid apes include the data from the literature, listed in Table 18.)

PRIMATE (both sexes)	TIBIA			
	Total	r.>	r.=l.	l.>
Man (all races)	734	40	15	45
Gorilla (all species)	147	39	22	39
Chimpanzee	96	39	24	37
Orang-utan	67	37	23	40
Hylobatidae (all species)	43	35	28	37
Macaque (all species)	105	51	21	28

TABLE 24

Percentage distribution of asymmetries in the combined length of femur and tibia of adult primates

PRIMATE (both sexes)	FEMUR + TIBIA			
	Total	r.>	r.=l.	l.>
Man (all races)	727	41	5	54
Gorilla (all species)	125	51	11	38
Chimpanzee	74	41	4	55
Orang-utan	45	44	16	40
Hylobatidae (all species)	20	50	10	40
Macaque (all species)	102	49	13	38

for the left and the right sides amount to only 11—18 per cent, whereas in man they are 47—60 per cent. In the orang-utan asymmetries of the arm favor most frequently the right side, as in man, but this inequality is not nearly as pronounced in the former as in the latter. In the comparatively small, combined series of gibbons and siamangs the conditions are not clear. In the macaque, finally, asymmetries favor both sides with practically equal frequency and this in the humerus, the radius and the combined length of the two. In all these groups of primates symmetry occurs more rarely in the total arm length than in the humerus or radius alone and the preference of asymmetries for one side is more marked in the former than in the latter.

In regard to asymmetries of the lower extremities man does not differ essentially from the other primates, as he does in regard to asymmetries of the upper extremities. The bones of the left lower extremities are somewhat more frequently the longer ones than those of the right lower extremities not only in man, but also in the chimpanzee (with the exception of the tibia). Indeed, the combined length of femur and tibia is longer in the left than in the right extremity in 14 per cent more of the cases than the reversed relation in chimpanzees, whereas in only 13 per cent in the series for man. Regarding the femur and the total length of the lower extremity asymmetries favor the right side slightly more frequently than the left in gorillas, orang-utans and Hylobatidae. Asymmetries in the tibiae show as a rule decidedly less preference of one side over the other than do asymmetries in the femora and in the total lengths of the lower limbs. As in the upper extremity, so in the lower one it is found that symmetry is rarer and asymmetries favoring one side are usually more frequent in the combined length of the two bones than in each segment alone.

According to the 36 diagrams for asymmetries of limb bones of the six groups of primates shown in Fig. 6, asymmetries in favor of the right side are more frequent than those in favor of the left in 18 instances, the reversed relation occurs in 17 instances, and once there exists no difference in the frequencies of both sides. Primates, therefore, differ in this respect from ungulates and rodents in which, as far as known, the left long bones of the limbs are the longer ones in the great majority of the cases (Weber, 1903, and Latimer and Riley, 1934).

The distribution of asymmetries in the lengths of the clavicles of man and other primates is shown by the data in Table 25 which served for the construction of the corresponding diagrams in Fig. 6. As in

TABLE 25

Percentage distribution of asymmetries in the clavicle of adult primates

PRIMATE (both sexes)	CLAVICLE			
	Total	r.>	r.=l.	l.>
Man (all races)	699	25	14	61
Gorilla (all species)	106	44	12	44
Chimpanzee	67	45	13	42
Orang-utan	45	44	18	38
Hylobatidae (all species)	17	47	18	35
Macaque (all species)	95	40	26	34

regard to the asymmetries of the upper extremities man differs from other primates in regard to the asymmetries of the clavicles since only in man is there a decided preponderance of asymmetries favoring one side. The differences between the frequencies of "right clavicles longer" and of "left clavicles longer" in Table 25 amount to 36 per cent in man, whereas to only 0 to 6 per cent in the great apes and the macaque. The corresponding data in the Hylobatidae are too scanty to be reliable and have been recorded merely in the hope that they will be added to in the future.

THE ABSOLUTE AND RELATIVE AMOUNT OF ASYMMETRY

In the study of asymmetries it is of interest to learn not only which side is the larger of the two, but also how much the two sides differ from one another in length. The data in Table 26 give an initial answer to the latter question, using as examples the lengths of the humerus and of the femur. In these average absolute differences between the corresponding dimensions on the two sides of the body, individual cases of (practical) symmetry figured as *0*. In adult man the two humeri differ in length on a general average for 4.1 mm., whereas the femora for only 2.5 mm. This is surprising and very significant in view of the fact that in man the femora are always longer that the humeri. In the macaque in which, as in man, the femora surpass the humeri in length

TABLE 26

Average absolute asymmetries (including cases of symmetry) in millimeters for the length of the humerus and the length of the femur

HUMAN RACE & SEX	HUMERUS	FEMUR	PRIMATE & SEX	HUMERUS	FEMUR
White ♂	3.6	2.8	Gorilla ♂	2.8	3.0
White ♀	4.0	2.2	Gorilla ♀	2.5	1.6
Negro ♂	3.7	3.0	Chimpanzee ♂	2.4	1.8
Negro ♀	3.0	2.4	Chimpanzee ♀	2.3	2.0
Eskimo ♂	4.1	2.5	Orang-utan ♂	2.4	2.0
Eskimo ♀	6.3	2.1	Orang-utan ♀	2.6	1.5
Indian ♂	4.9	2.6	*Average of*		
Indian ♀	4.7	2.6	*large apes*	**2.5**	**2.0**
Chinese ♂ ♀	2.8	2.5	*Hylobatidae* ♂ ♀ ..	**1.6**	**1.6**
Australian ♂ ♀ ..	3.6	2.1	*Macaque* ♂ ♀	**0.8**	**1.0**
Average of man	**4.1**	**2.5**			

the average absolute asymmetry of the femora is somewhat greater than that of the humeri, as might have been expected. In the great apes it is the humerus which usually exceeds the femur in length and in these primates the average asymmetry is correspondingly somewhat greater in the humerus than in the femur. In spite of the fact that male gorillas and male orang-utans have much longer humeri than adult man (see Table 5), the average asymmetry of the humeri amounts to 2.8 and 2.4 mm. respectively in the former, whereas to 4.1 mm. in the latter. Even though the femora of man are very considerably longer than the femora of the great apes, the average asymmetry in these bones is only 0.5 mm. greater in the former than in the latter. Man, therefore, appears outstanding among primates in possessing by far the most asymmetrical humeri. The absolute asymmetries, being influenced by the general size of the bones, are less useful in elucidating these problems than the relative asymmetries which express the difference between the right and

left sides in percentage of the smaller of the two measurements (cases of symmetry being recorded as equal *o*).

The averages of these relative asymmetries in the different races and the two sexes of man are listed in Table 27. In individual cases the relative asymmetries of human bones, to all appearance perfectly normal, can amount to as much as 7.1 (humeri of a male Negro) or even 9.6 (clavicles of a male white). The averages of the percentage asymmetries are in general very similar in the different racial groups and in both sexes, only the female Eskimos stand out by having exceptionally high values. From Table 27 it is evident that some of the various bones differ considerably in all races in regard to their average relative asymmetries. This is most clearly shown by the averages of all the relative asymmetries for each bone in the entire series of human skeletons.

TABLE 27

Averages of percentage asymmetries (larger measurement minus smaller measurement in percentage of smaller measurement, including cases of symmetry) in human races

RACE & SEX	HUMERUS	RADIUS	HUMERUS + RADIUS	FEMUR	TIBIA	FEMUR + TIBIA	CLAVICLE	MEAN OF FIGURES ON LEFT
White ♂	1.11	1.16	1.06	0.64	0.75	0.51	2.11	**1.05**
White ♀	1.37	1.48	1.34	0.55	0.86	0.57	2.11	**1.18**
Negro ♂	1.11	1.05	0.93	0.67	0.67	0.56	2.08	**1.01**
Negro ♀	0.98	1.29	0.95	0.58	0.69	0.54	1.92	**0.99**
Eskimo ♂	1.34	1.10	1.07	0.61	0.80	0.56	2.53	**1.14**
Eskimo ♀	2.26	1.34	1.75	0.56	1.04	0.60	2.37	**1.42**
Indian ♂	1.52	0.91	1.10	0.59	0.63	0.43	2.14	**1.04**
Indian ♀	1.60	1.16	1.31	0.67	0.72	0.52	2.00	**1.14**
Chinese ♂ ♀	0.92	1.07	0.92	0.64	0.69	0.50	2.95	**1.10**
Australian ♂ ♀	1.18	1.92	1.03	0.52	0.48	0.38	2.43	**1.18**

These amount to 1.28 for the humerus, 1.20 for the radius, 1.12 for humerus + radius, 0.61 for the femur, 0.75 for the tibia, 0.54 for femur + tibia, and 2.16 for the clavicle. The clavicles, therefore, are in general much more asymmetrical than the bones of the upper extremities and the latter are more asymmetrical than the bones of the lower extremities. That the lengths of the right and left clavicles differ considerably more from one another than the lengths of the right and left long bones of the limbs is true not only for man, but also for all the other primates in Table 28, as well as for platyrrhine monkeys (Schultz, 1926). The general average for the relative asymmetry of the humeri of adult man (1.28) is practically the same as the average percentage difference between the lengths of the right and left humeri in a series of 100 white fetuses which amounts to 1.30 (Schultz, 1926). This is very significant since it renders it most improbable that asymmetries become more pronounced with age or with the period of functioning of the bones. It may be mentioned here also that the author found an average percentage asymmetry in the lengths of the feet amounting to 1.40 in the same series of white fetuses and to 1.11 in a series of 500 white adults.

The average relative asymmetries of man are compared with those of other primates in Table 28. It is seen first of all that, according to the arithmetic means of all the averages in each row, man is in general more asymmetrical than any of the apes. The mean of the average relative asymmetries of the various bones amounts to 1.09 in man, it is much lower and remarkably uniform in the anthropoid apes, equalling from 0.85 to 0.87, and it is lowest in the macaque, being only 0.72. This significant difference in the degrees of asymmetries between man and all the other primates does not exist in all the bones studied, but only in the clavicles and in the bones of the upper extremities, i.e. in precisely the same bones which have been found to differ strikingly between man and the apes regarding the distribution of asymmetries. As shown by the last two columns in Table 28, the mean of the three averages appertaining to the upper extremity is on a general average practically the same as the mean of the three averages appertaining to the lower extremity in the great apes and the macaque, whereas in man the former mean is nearly twice as large as the latter mean. In other words, the average degrees with which the lengths of corresponding limb bones are unequal on the two sides of the body are approximately the same in man and the apes in the case of the lower extremities, but in the case of

TABLE 28

TABLE 28

Averages of percentage asymmetries (larger measurement minus smaller measurement in percentage of smaller measurement, including all cases of symmetry) in adult primates. The figures in parentheses give the numbers of skeletons upon which these averages are based

PRIMATE (both sexes)	HUMERUS	RADIUS	HUMERUS + RADIUS	FEMUR	TIBIA	FEMUR + TIBIA	CLAVICLE	MEAN OF FIGURES ON LEFT	MEAN OF 3 FIGURES FOR UPPER LIMB	MEAN OF 3 FIGURES FOR LOWER LIMB
Man	1.28 (735)	1.20 (737)	1.12 (722)	0.61 (744)	0.75 (734)	0.54 (727)	2.16 (699)	**1.09**	**1.20**	**0.68**
Gorilla	0.69 (127)	0.81 (130)	0.58 (119)	0.67 (135)	0.90 (128)	0.63 (125)	1.81 (106)	**0.87**	0.69	0.73
Chimpanzee	0.79 (82)	0.71 (83)	0.61 (74)	0.65 (79)	0.76 (84)	0.57 (74)	1.99 (67)	**0.87**	0.70	0.66
Orang-utan	0.77 (48)	0.76 (51)	0.63 (46)	0.68 (49)	0.87 (49)	0.55 (45)	1.69 (45)	**0.85**	0.72	0.70
Average of 3 large apes	0.75	0.76	0.61	0.67	0.84	0.58	1.83	....	**0.71**	**0.70**
Hylobatidae	0.66 (21)	0.95 (25)	0.50 (21)	0.81 (22)	1.07 (23)	0.70 (20)	1.35 (17)	**0.86**	0.70	0.86
Macaque	0.54 (104)	0.80 (104)	0.53 (103)	0.62 (102)	0.69 (105)	0.51 (102)	1.33 (95)	**0.72**	0.62	0.61

the upper extremities these degrees are much greater in man than in any of the other primates. It seems impossible at present to refer to any demonstrable cause for this interesting and definite finding. In view of his observations on asymmetries in human fetuses the author can not believe that the common preferential use of the right arm in man could be held directly responsible for the unique distribution and intensity of asymmetries in the human arms. To account for the latter in connection with "right-handedness" one would have to assume some sort of selection and hereditary fixation which had operated among random asymmetries or variations in two arms of man. Such a working hypothesis does not appear very plausible in consideration of the fact that real "left-handedness" is much rarer in man than are asymmetries favoring the left arms. Furthermore, in a recent study Busse (1936) concludes that asymmetries of the human body (chiefly the head) are not hereditary.

SUMMARY

This paper is intended primarily as a record of new and uniform data bearing upon variability and asymmetries in higher primates for comparisons between man and apes. The records collected furnished also information on the absolute size and on some proportions of the chief long bones of the limbs, on sex differences in size in apes and man, on the occurrence of septal apertures in the humeri examined, and on the frequency of old fractures in wild great apes. The data presented are based mostly on a total of 753 human skeletons, belonging to a variety of races, and a total of 530 simian skeletons, belonging to all genera of anthropoid apes and to macaques. The main results are briefly enumerated below:

1. Old healed fractures of the long bones of the limbs and the clavicles are found in nine per cent of the skeletons of adult, wild great apes and occur most frequently in the humerus.

2. Septal apertures in the humeri are more common in Negroes than in whites and more common in females than in males. Among the great apes these apertures are most frequent in orang-utans (over 80 per cent of the cases) and least frequent in chimpanzees (26 to 33 per cent). In Hylobatidae these apertures are extremely rare and in macaques they occur in only 4 to 10 per cent of the cases.

3. The sex difference in size, as judged by the lengths of the humerus and the femur, is greatest in the gorilla, also very pronounced

in the orang-utan, considerably less marked in man, and least of all in chimpanzee and macaque.

4. In man and macaque the femur is always longer than the humerus; in gorilla, orang-utan, siamang and gibbon the reversed relation exists in all cases. In 31 per cent of adult chimpanzees the femur is equally long or longer than the humerus.

5. The claviculo-humeral index is on an average lower in whites and Negroes than in Eskimos, Indians and Chinese. In gorilla, chimpanzee, siamang, gibbon, and macaque this index is lower than in man. Only the orang-utan surpasses man in this respect. This proportion has higher averages in males than in females in all human races studied and in all apes, except the chimpanzee which shows no such sex difference.

6. The intermembral index has significantly higher averages in males than in females in whites, Negroes, Eskimos, and Indians. In man this index lies always considerably below 100, whereas in the anthropoid apes without exception above 100. The intermembral index of the macaque lies between the indices of man on one side and of the anthropoids on the other side.

7. The brachial index is higher in Negroes, Indians and Chinese than in whites and Eskimos and it is higher in males than in females in all human races in which both sexes could be studied. The range of variations of this index in man overlaps extensively with the corresponding range in gorilla. Rare minimal values in chimpanzees can equal exceptionally high values in man. All other apes have higher brachial indices than man.

8. The crural index is much more uniform among the primates studied than the previous two indices. The proportionately shortest tibia is found in the gorilla.

9. The claviculo-humeral index is by far the most variable proportion and the intermembral index the most constant one intragenerically in man, the great apes and the macaque.

10. According to the arithmetic means of the variation coefficients for the six dimensions and proportions studied, there exist no significant race- or sex-differences in variability in man and the variability of the human races, taken singly, is approximately the same as that of the different apes. Man as a species and as one series containing many races can exceed some of the apes in regard to the total ranges of variations of the indices studied.

11. In all the human groups which were available asymmetries in the lengths of the humeri and the radii and in the added lengths of these two bones favor the right side in the great majority of the cases. Only in the humeri of male Negroes is this rule not very evident. Asymmetries in the upper extremities favoring the right side are more frequent in females than in males among whites, Negroes, Eskimos, and Indians.

12. In the lower extremities asymmetries favor more frequently the left than the right side in all human races and both sexes, with the exception of the tibia of male Negroes. This preponderance of one side is not nearly as marked in the lower extremities as it is in the upper ones.

13. Asymmetries in the lengths of the two clavicles favor the left much more frequently than the right in all human races.

14. In comparing the distribution of asymmetries in man (as *one* series) with that in the apes and the macaque it is found first of all that, in general, cases of symmetry are rarer in the former than in the latter. Asymmetries in the bones of the upper extremities favor more frequently the right side than the left in orang-utan, as in man, and more frequently the left side than the right in gorilla and chimpanzee. The preference of asymmetries for one side is, however, not nearly as marked in the apes as it is in man. In the macaque asymmetries favor both sides with practically the same frequency. In all the primates studied asymmetries show a greater preference of one side over the other in the case of the combined length of humerus and radius than in the case of humerus length or radius length alone.

15. In regard to asymmetries of the lower extremities man does not differ essentially from the other primates as he does in regard to asymmetries of the upper extremities, since in all primates there is comparatively little preference of one lower extremity over the other. In chimpanzee, as in man, asymmetries tend to favor the bones of the left lower extremity more frequently than those of the right. In gorilla and orang-utan the opposite condition prevails. Asymmetries of the tibiae show as a rule decidedly less preference of one side over the other than do asymmetries in the femora and in the total skeletal lengths of the lower limbs.

16. Asymmetries in the lengths of the clavicles favor both sides with practically equal frequency in gorilla and chimpanzee and the right side slightly more frequently than the left in orang-utan, Hylobatidae, and the macaque. This contrasts strikingly with the conditions in man

in whom the left clavicles are the longer ones in 61 per cent, whereas the opposite in only 25 per cent of the cases.

17. On a general average (including all cases of symmetry) the lengths of the two humeri differ in man for 4.1 mm. and the lengths of the two femora much less, namely for only 2.5 mm. In the great apes the corresponding figures are much more alike, i.e. 2.5 and 2.0 mm.

18. The relative asymmetries (difference between right and left lengths in percentage of smaller measurement) are much more pronounced in the clavicles than in the long bones of the limbs and are somewhat greater in the single long bones than in the added lengths of humerus and radius or of femur and tibia.

19. The average relative asymmetries of the clavicles, the humeri, the radii, and the added lengths of the latter two are much higher in man than in any of the other primates studied, but the average relative asymmetries of the femora, tibiae and added lengths of these two bones are practically the same in man as in the apes and monkeys.

It has been possible to demonstrate conclusively that man differs strikingly from apes and monkeys in regard to both the percentage distribution and the relative amount of asymmetries of the clavicles and the long bones of the upper extremities; and that man and other primates are practically alike in regard to the degree of asymmetries and the difference in the preference of asymmetries for the two sides in the long bones of the lower extremities.

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TWINNING IN STUTTERING FAMILIES

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FOR many years stuttering was regarded purely as a psychosocial phenomenon. There grew up around it a complex therapy with roots, curiously enough, in such unneighborly soils as Freudianism and elocution. As workers studied the stuttering child more carefully however, and found him apparently normal in all adjustments except speech, the charge of psychic morbidity found itself on shifting sands. If it had any place at all in the stuttering picture its relegated position was one of effect rather than cause.

Attention shifted to more elusive but more basic physiological considerations. Certainly, the scholar argued, a disorder so tenacious in its hold must be implanted in an endocrine, or neurological, or hematorespiratory imbalance. Valuable contributions suggesting such a disturbance have been made in this field. The evidence still is inconclusive.

The present research shifts the angle of the perspective again, but this time in the same general direction. The inheritance of stuttering has been postulated for a number of years. Boome and Richardson[1] quote Denhardt for their statement that in the London Centres for Stammering Children, 78 per cent of the stammerers possessed a stammering heritage. In a careful study made at the University of Wisconsin[2] of 127 families of stutterers and 127 families of non-stutterers, it was revealed that among the stutterers 71.7 per cent showed some incidence of stuttering in the family background whereas in the families of 127 non-stutterers, 14.1 per cent showed some incidence of stuttering.

The implication that an hereditary sub-soil obtains receives support from our recent study of stuttering. From our observations we are lead to believe that: (1) There is a tendency for twinning to occur more

[1] Boome, E. J. and Richardson, M. A. The Nature and Treatment of Stammering. p. 202. E. P. Dutton and Co. 1932.

[2] Wepman, J. M. Is Stuttering Inherited? M. A. Thesis, University of Wisconsin, 1934.

frequently in families containing stutterers than in families composed of non-stutterers, (2) In stuttering families containing both twins and single siblings, stuttering is more frequent among the twins than the single siblings. Our observations originally were based on the study of the medical and family records of 500 stuttering and 500 non-stuttering children. Because certain records of the stutterers were deemed incomplete from a medical point of view, 39 cases finally were discarded. The final comparisons, therefore, were made on 461 stuttering children and 500 non-stuttering children. The findings were incidental in a comprehensive project to determine whether stuttering is a sequela of any disease or group of diseases. The medical records were secured through the cooperation of four Chicago Hospitals: Billings and Bobs Roberts Hospital, Children's Memorial Hospital, Rush Medical Clinic, and Michael Reese Hospital. In securing the records of a control group of children entered for routine pediatric care, the cooperation of the Illinois Institute for Juvenile Research, Elizabeth McCormick Fund, Jewish Home Finding Society, Chicago Orphans Asylum, and the Illinois Children's Home and Aid Society was of material assistance. The family record filled out on the admission of the child to the clinic or hospital probably is more accurate than the usual social history inasmuch as it included the birth order, still births and miscarriages.

A forword to the tables which present the salient data will add to their comprehensibility. It should be noted, first of all, that there is only one basis of selection of the groups which enters into this comparison. The children in the control group were chosen because there was no stuttering present in the child or in the family as far as it could be learned. The comparison, therefore, is between *stutterers* and *non-stutterers*. Secondly, the twin may or may not have been a stutterer. Hence, there are two columns in Table 1, listing first the twins, one or both of whom stutter, and secondly, the twins who do not stutter but who are brothers or sisters of our propositus, a stutterer. Likewise in the control group there are two columns. In the first column are listed the twins, one or both of whom were propositi in our study. In the second column the twins who were brothers or sisters of our propositus are listed.

In the 461 families of stutterers there are 1628 children. Thirty of these families have one pair of twins each. One family has two pairs of twins and no single births. There are 430 families with single births only. In the twenty families containing one pair of twins, *and one or*

both of whom stuttered, there were 60 siblings, of whom 3 stuttered. In the 10 families containing 1 pair of twins, *and neither of whom stuttered,* there were 39 single siblings, of whom ten stuttered.

It was impossible to determine whether the twins were monozygotic or dizygotic. In three instances, the hospital record specified that the cases were monozygotic, but inasmuch as these statements did not come from the hospital where the twins were delivered, it cannot be considered a verified record. It is interesting to note in passing that in two of the three cases both members of the pair stuttered. If we accept the ratio 1:3 set by Duncker in 1915[3] and reiterated by Hamlett[4] in 1935, eleven pairs should be monozygotic.

TABLE 1

Twinning in stuttering and non-stuttering families

TWINS (one or both propositi)	A. STUTTERERS' GROUP (461)		
	Non-stuttering twins	Total no.	Total no. siblings in family
FF 5	FF 3		
MM 12	MM 6		
MF 4	MF 2	32	1628

	B. CONTROL GROUP (500)		
TWINS (one or both propositi)	Twins in family (brother or sister the propositus)	Total no. of twin pairs	Total no. siblings in family
FF 2	FF 2		
MM 4	MM 4		
MF 0	MF 3	15	1657

[3] Duncker, G. Die Frequenzverteilung des Geschlechts-Kombinationen bei Mehrlingsgeburten des Menschen und des Schweins. *Biol. Zentralblatt*: 35: 506-39. 1915.

[4] Hamlett, G. W. D. Human twinning in the United States; Racial frequencies, sex ratios and geographical variations. *Genetics*: 20 (3): 250-58. 1935.

TABLE 2

Comparison of ratios: twins to single births in stuttering and non-stuttering families

Stutterers' group	*Control group*
1: 50.8	1: 110.4

TABLE 3

Stuttering in families containing both twins and single siblings
(Note: 5 twin children died before the onset of speech. 2 pairs of twins have no single siblings in the family)

	Twin Children		*Single Children*	
Total no. of families	*No.*	*No. who stutter*	*No.*	*No. who stutter*
30	55	22	99	13

From Table 2, it is evident that the ratio of plural to single births in the stuttering group is twice as high as that for the control group. Although no comparison can be made because of the inequality in the size of the two groups, it should be noted that in Zeleny's[5] interpretation of the birth statistics in 1917 the ratio of plural to single births is 1:93.1. Hamlett[6] who made a similar analysis of 18,000,000 births reported by the Census Bureau in 1933 found the ratio of plural to single births to be 1:87.3.

To measure the reliability of our observation that twinning is more frequent in stuttering families than in non-stuttering families we have applied Pearson's chi-square test.[7] The chi-square value of 6.55, gives a probability of 0.01 which denotes a statistically significant deviation.

Table 3 embraces the material from which we conclude that in families containing twins and single siblings stuttering is more frequent among the twins than among the single siblings. The chi-square value

[5] Zeleny, Charles. The relative number of twins and triplets. *Science*: 53: no. 1368: 262-63. March 18, 1921.

[6] Hamlett, G. W. D. Human twinning in the United States: Racial frequencies, sex ratios and geographical variations. *Genetics*: 20 (3): 250-58. 1935.

[7] Formula found in Fisher, R. A. Statistical Methods for Research Workers. pp. 75-98. 4th edition. Oliver and Boyd, *London*. 1932.

is 8.75. The chances that a table would have a chi-square value as large or larger than the one exhibited, by pure accident, are between three and four in one thousand.

In order to evaluate the place of twinning in the etiology of stuttering it is necessary to bring together the heritable factors which have been associated with multiple births and with stuttering. A review of the research on these two phenomena may prove tedious to the reader but it is essential for the establishment of a common denominator, even though it be a hypothetical one.

TWINNING

The three possible types of twins are familiar to every biologist: (1) The cleavage of an ovum fertilized by one spermatozoon (monozygotic or identical twins); (2) Two ova fertilized by two spermatozoa (dizygotic or fraternal twins); and (3) An ovum divided into two identical portions (or a definitive ovum and its second polar body) and fertilized by different spermatozoa.

According to Hamlett[8] identical twins in the United States form 33 per cent of the total in whites, but less than 29 per cent in Negroes. Duncker[9] estimates from his study of 1000 twins and 1000 triplets that one third of all twins and one fourth of all triplets are monozygotic.

The secondary sex ratio approaches parity. In 1933 in the United States there were born 8,421 pairs of male twins, 8,098 pairs of female twins, and 8,471 pairs of opposite-sex twins.[10] Although the presence of a common chorion for the two fetuses is fairly reliable clinical evidence for monozygotic twinning, hospital records still do not specify the type, and consequently, there is no infallible way of determining what proportion of the multiple births in 1933 was monozygotic. Both types of twinning probably are far more common than the birth statistics indicate.

How is twinning produced? The answer to this question is theoretical. There now are two modes of emphasis. Newman and Stockard stress the physiological factors in twinning. Davenport, Danforth, Dahlberg, Greulich and Hamlett place great emphasis upon the rôle of heredity.

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[8] Hamlett, G. W. D. *op. cit.* pp. 250-58. 1935.

[9] Duncker, O. *op. cit.* pp. 506-39. 1915.

[10] United States Department of Commerce, Bureau of the Census; 19th annual report. p. 132. 1933.

It is apparent that the two points of view are not inconsistent. Heritable factors are expressed through physiological channels. Newman[11] through his research on multiple births in the armadillo, postulates that in man twinning may be caused by one of two physiological disturbances: (1) understimulation of the egg, due to some defect in the development-initiating mechanism of the sperm, and (2) belated placentation. Newman[12] states: "If the egg were retarded through insufficient stimulation on the part of the sperm it would probably undergo bilateral fission, the consequences of which would depend upon the degree of retardation." Stockard[13] in 1921 carried this theory forward another step by attributing the "loss of dominance" of the original axiation to a deficiency in the oxygen supply during the free vesicle period (lack of connection with the uterine mucosa).

Twinning also might be produced by "belated placentation, due to a failure of the corpus luteum to stimulate the uterine muscosa". This condition, says Newman,[14] "merely implies some physiological discoordination between the various intricately interdependent factors responsible for implantation of the ovum. The weakness of this view is that the same mechanism would presumably persist throughout the reproductive life of a given mother and she should always produce twins. Such a condition, however, does not prevail, for almost without exception mothers of one-egg twins have also single children. It is barely possible, however, that cases of single off-spring from parents exhibiting one-egg twinning are not true single off-spring but that each is the survivor of a pair of twins, one of which has succumbed to the ever-present hazards that prevail especially in connection with one egg twinning. On the whole this seems to be the least objectional causal theory of twinning in man."

At what stage the twinning impluse appears is not known but Arey[15] states that "there is considerable evidence to support the belief that the twinning impulse occurs relatively late at about the moment of

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[11] Newman, H. H. The Physiology of Twinning. pp. 133-34. University of Chicago Press. 1923.

[12] Newman, H. H. *ibid.* p. 133.

[13] Stockard, C. R. Developmental rate and structural expression: An experimental study of twins, 'double monsters' and single deformities, etc. *American Journal of Anatomy*: 28: 115-266. 1921.

[14] Newman, H. H. *op. cit.* pp. 133-34.

[15] Arey, L. B. Developmental Anatomy. p. 163. W. B. Saunders Co., *Philadelphia.* 1934.

gastrulation, which in man corresponds to the formation of a primitive streak". Hinrichs and Genther[16] who produced twins in fundulus by exposure of the eggs to ultra violet radiation found that "the greatest percentage of twin formation occurred at times when the axial relations in the embryo are easily disturbed".

But despite the fact that Arey, Hinrichs and Genther lend support to Newman's study, they do not deny the importance of inheritance. Hinrichs and Genther[17] state: "There appears to have been a primordial difference in the susceptibility of the egg protoplasm at the time of exposure or a latent period of activity of radiation effect, or both". Arey[18] calls attention to the fact that "in fishes separate embryonic axes, and hence two embryos, are obtainable experimentally through lowering the temperature or reducing the oxygen supply at a particular moment during development". That separate axes may arise is not unreasonable, Arey believes, for "the periphery of the blastoderm possesses many potential points where an embryonic axis might arise. In ordinary single development one such growing point, apparently by virtue of some favorable positional advantage, gains the supremacy and suppresses all other potential axes, just as the terminal bud does the lateral one in some plants. If, however, the developmental rate is slowed at the critical moment when the preferred axis is about to assert its dominance, this momentary advantage is lost and one or more neighboring points can then compete on more equal terms and may even assert themselves as additional embryonic axes." Arey[19] recognizes that this process may itself be heritable: "In uniovular twins the egg may receive lethal factors incompatible with the completion of development. Theoretically it is possible that there may be some hereditary tendency, like a tardy preparation of the uterus for the reception of the embryo which leads to effective delays in implantation; of such factors nothing is known."

Jordan and Kindred[20] likewise recognize the inheritance of twinning: "A chemical factor in the sperm might be responsible for the disjunction

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[16] Hinrichs, Marie A. and Genther, Ida T. Ultra-violet radiation and the production of twins and double monsters. *Physiological Zoology*: 4; no. 3: 480. 1931.

[17] Hinrichs, Marie A. and Genther, Ida T. *ibid.* p. 465.

[18] Arey, L. B. *op. cit.* p. 163.

[19] Arey, L. B. *op. cit.* p. 166.

[20] Jordan, H. E. and Kindred, J. E. A Text Book of Embryology. p. 526, D. Appleton and Co. 1932.

of the blastomeres or the fission of the later embryonic axis. There may be a factor of developmental arrest at critical stages in twin production: this factor could be inherited."

Newman's concept of the physiology of twinning has not met with general acceptance among geneticists. Davenport, Danforth, Dahlberg, Greulich, and Hamlett do not agree with Newman that environmental factors in embryo may be responsible for the production of twins. Hamlett[21] points out that polyembryony does not occur in other animals that have the quiescent state described by Newman in the armadillo, and that furthermore, there is no quiescent state in the human embryo. He sums up his position in these words: "There must be some inherent difference in the ova of the two species, controlled by some gene or set of genes. The physiology of twinning is not dependent upon external factors of the environment; it is governed by intrinsic, hereditary potentialities of the fertilized ovum."

Danforth[22] studied fifty families in which twins occurred. He found that fifty pairs of new born twins had 171 singly born brothers and sisters, a ratio of 1:18. Further, in respect to the mothers of these twins, their brothers and sisters numbered 319 single births and 10 pairs of twins, a ratio of 1:32. Lastly, the fathers of the fifty pairs of twins had 210 brothers and sisters, born singly and 8 pairs of twin brothers and sisters, a ratio of 1:37. Danforth concludes that there is an hereditary tendency toward twinning.

The results of Greulich's investigation[23] of 495 pairs of twins strengthen the claim of heredity. "It is concluded that the parents of our cases produce twins with a greater frequency than would be expected if the trait was due to chance alone." Greulich also denies assumptions which have been made by earlier writers: "Dizygotic twinning is not a sex-limited trait. The genotype of the father is as important as that of the mother for the production of this type of twin. It is not a sex-linked dominant. It is probably not a simple mendelian recessive. Dizygotic and monozygotic twinning are not different expressions of the same twinning tendency; on the contrary they seem to be phenomena quite distinct from each other."

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[21] Hamlett, G. W. D. Polyembryony in the armadillo. *Quarterly Review of Biology*: 8: 358. 1933.

[22] Danforth, C. H. Is twinning hereditary? *Journal of Heredity*; 7: 195-202. 1916.

[23] Greulich, W. W. Heredity in human twinning. *American Journal of Physical Anthropology*: 19: 409. 1934.

Dahlberg[24] would disagree with Greulich's last sentence, for he believes that the two phenomena are very closely associated. Twin pregnancy, Dahlberg assumes, is caused by the presence of a "doubling tendency", manifesting itself either before the reduction divisions, or after fertilization. In the former case the result will be follicles containing two or more ova, and after ovulation dizygotic or a higher order of multiple pregnancy may obtain. In the second case monozygotic twins, or triplets, are produced. Simultaneous bursting of two follicles, however, may produce a dizygotic pregnancy. The observed increase in the freqency of dizygotic twinning with increasing age of the mother possibly may be explained in this way. Johansson[25] reporting Dahlberg's hypothesis, concludes that "if this is the true explanation of the facts the mother who has a hereditary tendency to produce dizygotic twins should at the same time show a predisposition to produce monozygotic twins".

These are the present day concepts of twinning. They are not irreconcilable or basically inconsistent views. There is a strong argument, for believing that in twinning heredity "pulls the long oar".

Physiologists and psychologists have found twins a fascinating subject for study. Studies by Westergaarde,[26] Wilson and Jones,[27] Newman,[28] and Stocks[29] give evidence that one member, at least, and possibly both members of the pair, begins life with a physical handicap. Merriman[30] found "no evidence which warrants the assumption that twins are intellectually handicapped". These studies are not reported in detail because they bear only indirectly on the present problem. From the point of view of this study, perhaps the most thought-

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[24] Dahlberg, G. Twin Births and Twins from a Hereditary Point of View. pp. 266-96. *Stockholm*, 1926.

[25] Johansson, Ivar. The sex ratio and multiple births in cattle. Paper from the Department of Genetics; *Agricultural Experiment Station*, University of Wisconsin; no. 109. 1932. Also published by *Zeitschrift für Züchtung: B. Tierzüchtung und Züchtungsbiologie*. B. 24. Heft 2 S. 165-328 Bln. 1932.

[26] Westergaarde, H. Zur Statistik der Mehrgeburten. *Allg. stat. Arch.* Bd. 2. S. 509. 1891-92.

[27] Wilson, P. T. and Jones, H. E. A study of like-sexed twins. *Human Biology*: 3: 107-32.

[28] Newman, H. H. *op. cit.* p. 135-58.

[29] Stocks, P. A biometric investigation of twins and their brothers and sisters. *Annals of Eugenics*: 5: 1-56. Jan. 1933.

[30] Merriman, Curtis. The intellectual resemblance of twins. *Psych. Monographs*. 33: no. 5. 1924.

provoking contributions by psychologists have been the study of the language problems and of handedness of twins.

In another section of this study (to be reported elsewhere) the stutterer was found to be seriously retarded in the initiation of speech and in the development of intelligible speech. In the light of this observation, it is most interesting that Dr. Dewey[31] reports in her book, *Behavior Development in Infants,* that "studies on twins seem to indicate that language development is retarded, probably because communication between them is socially satisfying at each developmental stage." Hirsch[32] describes an articulatory disorder in two pairs of twins in his study. On one pair he comments: "Lydia is left handed; Lauretta is right handed. Each has a slight impediment in her speech which makes it almost impossible for either of them to sound certain consonants, especially r. This, of course, makes them poor readers." In a study of monozygotic triplets, Clarke and Revell[33] note that "Albert is right handed but Edward and George are left handed. Each of the boys enunciates words poorly."

In the study of left handedness in twins, the work of Lauterbach[34] and Hirsch[35] is representative of the conclusions of numerous students of the problem.

After studying 240 pairs of twins, Lauterbach[36] concludes: "My data show that at least 19 per cent of all twin pairs are composed of a right and a left hander. Left-handedness is closely associated with twinning. This is evidenced by the large number of twins who are left handed, by a study of the genealogies of twin-bearing families, and by the circumstance of *situs inversus viscerum* among both twins and left-handed individuals. It may be that left-handedness and twinning are the result of identical or similar causes." To substantiate this significant statement, Lauterbach[37] cites cases from which I have selected

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[31] Dewey, Evelyn. Behavior Development in Infants. p. 277. Columbia University Press. 1935.

[32] Hirsch, N. Twins: Heredity and Environment. p. 111. Harvard University Press. 1930.

[33] Clarke, A. E. and Revell, D. C. Monozygotic triplets in man. *Journal of Heredity* 21: no. 4: 149. 1930.

[34] Lauterbach, C. E. Studies in twin resemblance. *Genetics*: 10: 528-68. November 1925.

[35] Hirsch, N. *op. cit.*

[36] Lauterbach, C. E. *op. cit.* p. 567.

[37] Lauterbach, C. E. *op. cit.* p. 538.

the following: "X, a right-handed female twin, married and gave birth to a girl with a crown which whorled to the left, who in turn gave birth to left-handed daughter. The daughter bore 7 children, four boys and three girls, of whom one boy is left-handed, and one has a double crown; and one girl is left-handed. Twin Y, the sister of X, bore a left-handed daughter."

There is another implication arising from Lauterbach's study. It is the high sex ratio of left handedness, both in single births and in twins. It should be noted that the high sex ratio in stuttering has been established by a number of scholars. In our study of 500 stutterers, the ratio is 3.6 to 1. Dr. Robert West,[38] chairman of the White House Conference survey of disorders of speech, states: "The ratios of stuttering boys to girls above 36 months of age vary all the way from three over one to eight over one." Lauterbach does not discuss the significance of the predominance of males but his figures and those of Jones are of great interest to us in view of the established high sex ratio among stutterers. Lauterbach[39] states: "Jones reports 4 per cent of the population as natively left-handed. It is interesting to note that of the total number of 793 left-handed individuals examined by Jones, 498 are males and 295 are females, 63 per cent males, 37 per cent females. Of the 36 left-handed twins examined by myself, 23 or 58 per cent are males; 17 or 42 per cent are females."

Hirsch[40] calls attention to the fact that "left-handedness is found in about 4 per cent of the population at large. Twins, it will be recalled, form less than 2 per cent of the general population", yet Hirsch found among "58 pairs of dissimilar twins, 12 per cent with one left-handed member; among 43 pairs of similar twins, 18 had left-handed members (42 per cent). The percentage of left-handed members of all 101 pairs is 25 per cent. Left-handedness is six times as frequent among twins as in the population at large."

The essential argument for us is found in this summary by Hirsch[41]: "The tendency to twinning and the tendency to left-handedness have some causal association. Whether twinning tends to cause left-handed-

[38] West, Robert. Disorders of Speech, Reading and Writing. Practice of Pediatrics. Vol. IV; chapter 14; p. 24. Brenneman, Joseph, ed. W. F. Prior and Co. Hagerstown. 1937.

[39] Lauterbach, C. E. The Psychology of Twins. Doctoral dissertation, University of Wisconsin. 1924. p. 40.

[40] Hirsch, N. *op. cit.* p. 38.

[41] Hirsch, N. *op. cit.* p. 38.

ness, or vice versa, or both are conditioned by a common cause, is unknown. However, that these two tendencies are clearly found together is undeniable."

The relatively high incidence of sinistrality in twins has given rise to several hypotheses. Lauterbach[42] goes so far as to ask, "Is it not quite possible that we have in the left-handed individual of a single birth the surviving axis of a bi-axiate egg which might have produced twins had not one axis been suppressed," Others have connected the sinistrality of twins with the phenomenon of *situs inversus* but the relationship is not clear and, in any case, it cannot account for the large number of left handed twins. Newman[43] says on this point: "There is no reason to expect to find *situs inversus* except in double individuals derived from the antimeric halves of a single embryonic axis. In the case of two embryos derived from two embryonic shields, each of which has its own right and left hand sides, we see no reason in the world why there should be a reversal of the viscera. Each is from the beginning a separate individual except that it happens to be on the same yolk sac as its twin partner. It would also be impossible to say which of such twins is the right hand and which is the left hand component."

It is not possible at the present time to offer a satisfactory explanation of the relationship between twinning and handedness. The only fact which has been safely established is that such a relationship does exist.

LEFT HANDEDNESS

The relationship between left handedness and twinning has been discussed in detail in the preceding section. On the connection between speech defects and left handedness, many contributions have been made. In 1911, Ballard[44] made a questionnaire study of 13,189 children and reported that stuttering was approximately four times more frequent among dextro-sinistrals (children naturally left-handed, who from early childhood had been trained to use the right hand) than among the rest of the children.

In a survey of 89,057 pupils in the St. Louis public schools, Wallin[45]

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[42] Lauterbach, C. E. *op. cit.* p. 40.

[43] Newman, H. H. *op. cit.* p. 172.

[44] Ballard, P. B. Sinistrality and speech. *Journal of Experimental Pedagogy*: 1: 298-310. 1911.

[45] Wallin, J. E. W. Studies of mental defects and handicaps. *Miami University Bulletin*, Series 22. no. 5. 1924

found that 2 per cent of the total school population were dextro-sinistrals, whereas 9.5 per cent of the stutterers were dextro-sinistrals.

Milisen[46] reports from his study of 23 stutterers at the University of Iowa that 82 per cent recorded left handedness in their hereditary background, and of 28 former stutterers, 84 per cent reported left handedness in their hereditary background.

Travis[47] and colleagues at the University of Iowa originally maintained that many stuttering children were natively left handed but, through the pressure of a right handed society, had built up a "lead" in the originally non-dominant hemisphere. The conflict between the hemispheres for control of mid-line organs produced stuttering. Recently these workers have modified their original position to include the possibility that the stutterer's difficulty is caused by a failure to establish any unilateral dominance in the cerebral hemispheres. Travis[48] states: "In the stutterer, central nervous system organization is characterized by a high degree of ambilaterality, in contrast to the relatively high degree of unilaterality which characterizes central nervous system organization in the normal speaker." Here he does not link ambilaterality with a post-natal shift in handedness. The position of Travis and co-workers has shifted, therefore, from an unqualified stand that the post-natal development of a cerebral conflict by a shift in handedness produced stuttering to the less spectacular and somewhat ambiguous view that the stutterer either develops or is born with a high degree of ambi-laterality.

Quinan[49] in a study of sinistrality and speech defects, published in 1921, does not attempt to show any causal relationship. He observes that "as compared with dextrals, stammering occurs in sinistrals with a frequency from three to seven times greater". It must be noted that Quinan is writing, not of sinistrals who have been shifted, but of pure sinistrals who as adults are left handed in all major activities. Quinan is linking stuttering with a native left handedness, not with a shift in handedness.

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[46] Milisen, R. A. A Comparative Study of Stutterers, Former Stutterers and Normal Speakers whose Handedness has been Changed. Thesis, University of Iowa. 1933.

[47] Travis, L. E. Speech Pathology. D. Appleton and Co. 1931.

[48] Travis. L. E. and Johnson, W. Stuttering and the concept of handedness. *Psychological Review*: 41: 55. 1934.

[49] Quinan, Clarence. Sinistrality in relation to high blood pressure, and defects of speech. *Archives of Internal Medicine*: 27: 255-61. February 1921.

Although the connection between stuttering or twinning and the experimental production of left handedness may seem remote, we wish to call attention in passing to the experiment performed on vitamin B depleted rats by Tsai and Maurer at the University of Chicago.[50] Tsai and Maurer made the tests of handedness by putting the "animal in a wire cage with a small glass bottle of wheat embryo inserted through the wire bottom. The opening of the bottle was so small (three-fourths inch in diameter) that it permitted the rat to use only one hand at a time for grasping food out of the container. Two hundred and fifty observations were made on each animal." One hundred and fifty-nine rats were so studied. Of this number, 105 were normal rats; 54 were vitamin B depleted rats who suffered through the depletion of their mothers during the nursing period. Among the normal rats, 31 per cent of the males and 46 per cent of the females were found to be left handed. In the vitamin B depleted rats 50 per cent of the males and 57 per cent of the females were left handed. In view of our finding reported earlier in this paper that the stutterer, although exhibiting a normal intelligence quotient, is retarded in the initiation and development of speech, Tsai and Maurer's concluding comment is intriguing[51]: "Comparison of the results indicates that the percentage of left handedness is higher in the vitamin B depleted animals whose maze-learning ability was found to be much inferior to that of normal rats. These results do not necessitate the conclusion that the left handed are mentally inferior. They merely indicate that the percentage of left handedness is higher among poor learners, and that's all."

The crucial question still to be answered is: How may the linkage between twinning and stuttering and handedness be interpreted?

The bulk of evidence presented here is in favor of the heritability of twinning. It may be assumed that left handedness is inherited. The present research strengthens the theory of the inheritance of stuttering. It would be easy enough to say that each phenomenon is inherited independently, but this does not seem likely in view of the fact that these factors tend to appear together and to have properties in common. Left handedness and twinning and stuttering tend to occur together. Sinistrality and stuttering both exhibit a high sex ratio. At first glance, one might say that the connection between twinning and stuttering is obvious.

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[50] Tsai, Loh Seng and Maurer, Siegfried. Right handedness in white rats. *Science* (N. S.): 72: no. 1869: 436-38. October 24, 1930.

[51] Tsai, Loh Seng and Maurer, Siegfried. *op. cit.* p. 438.

The member of the pair who natively should have been left handed has been forced to devolop dextrality; as a result of the dual dominance in the cerebral hemispheres there is a conflict for control of the speech organs. The child stutters. This theory is logical. The only difficulty is that it conflicts with the known facts. There are, for example, two pairs of male twins in the family of Number 53. (The younger pair, now 20 months old, has not developed speech.) Both of the older twins stutter, although No. 53 stutters more severely than his brother. Numbers 74 and 75 are recorded as identical twins. No 74 is left handed in all activities; 75 is right handed in writing, sighting, batting a ball, in all activities except eating. Both stutter. Numbers 279 and 280 are recorded as identical twins. Both stutter. The physician who delivered No. 459 noted in the record that the twins were monozygotic. No. 459 who was delivered first, is left handed, stutters. His twin died at birth. No. 165 is a fraternal twin (MF); he is left handed in all activities; he stutters. His twin sister is right handed and developed normal speech at 18 months. When one remembers the pressure of a right handed society, it seems highly improbable that the twins who natively should be right handed are actually left handed. Yet if this evidence is to support the "hemispherical dominace" theory such an assumption would have to be made.

It is to be regretted that only the history of the immediate family is recorded routinely, and only occasional references are made to grandparents, uncles, aunts, and cousins. The medical records indicate, however, that stuttering and left handedness tend to appear in the same family but that very often they do not reside in the same person. No. 438 serves as an example: Two of the father's sisters are left handed but they do not stutter. A third sister of the father of our patient is left handed and stutters. Her son stutters; her granddaughter is left handed but does not stutter.

No. 36 is another stutterer. His paternal uncle stutters. The daughter of the paternal uncle is ambidextrous but does not stutter. No. 77 stutters; his father is left handed but has never stuttered.

In passing, it is interesting to note that No. 13, not a twin but a stutterer, has twin cousins who stutter. Although there are no twins in the immediate families of Nos. 111 and 371, the maternal grandmother of No. 111 bore three pairs of twins and one set of triplets; and the paternal grandmother of No. 371 bore two pairs of twins. The mother of No. 199, by her first marriage, bore four children, all single births.

None stuttered. By her second marriage she had one pair of twins and two single births. Both single siblings stuttered.

Although these examples do not warrant a generalization, they contra-indicate the assumption that twinning *per se* produced stuttering, or that left handedness *per se* produced stuttering.

The relationship between and among these factors is not obvious. In view of the established connection between left handedness and twinning, both hereditary phenomena, one is inclined to treat with skepticism any theory of stuttering based on a post-natal development of cerebral confusion through a change in native handedness. I repeat that left handedness and stuttering tend to appear together but no causal relationship between the two has been established.

The results of this study indicate that twinning and stuttering also tend to appear together, but we have not explained the relationship. We can offer only a general hypothesis. Is it possible that the nervous dysfunction which obtains in stuttering is part and parcel of the same factor in the germ plasm responsible for multiple births? If the genetic complex is responsible for the retarded axiate growth at a critical moment in the embryo's life, then it may be responsible at the same time for the retardation in the neural patterns necessary for integrated speech. To carry the argument further back, the factor in the germ plasm producing twins may be a gene establishing an abnormal biochemical relationship, favorable to the retardation of a single axiate production, unfavorable to normal speech. One cannot forget the thesis of an atypical metabolism in stutterers, a fact which Kopp[52] clearly illustrated. Mention was made earlier of the experimental production of twins in lower forms by the irradiation of ultra-violet light and of the experimental production of left handedness by a vitamin B depleted diet. Is it possible that the genic force favorable to twinning and to stuttering may show itself in some process connected with vitamin metabolism? It is conceivable that the chemical imbalance might be sufficient to change the permeability of cell membranes and so alter healthy reception and conductivity.

The theories just expressed may be reiterated for left handedness. Left handedness and twinning may be a part and parcel of the same basic phenomenon although they may have no direct effect on each other. Following Lauterbach's reasoning, it may not be too far afield

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[52] Kopp, George. Metabolic studies of stutterers. *Speech Monographs*: 1; no. 1. September 1934.

to suggest that many of the left handed stutterers may have lost their mates in utero; they were, in origin, twins. Biologists now are inclined to look upon autolysis of embryos as a common occurrence.

If we pursued Newman's line of reasoning we might argue that the interference with fetal circulation which may occur in twinning could affect both of the centers normally dominant in establishing handedness and speech. The brain stands oxygen loss badly. Neural tissue probably would be the first to suffer injury by any interference with normal nutrition.

Now, what can be said for the high sex ratio in stuttering? Again, we must begin with a genetic background. Since left handedness also exhibits a high sex ratio, we must conclude that the factors responsible for both are present more frequently in males than in females. Those who accept Newman's concept of the physiology of twinning may argue that males make higher metabolic demands in utero and consequently will suffer greater hazards with any atypical condition.[53] Stuttering and left handedness, if they are to be linked with a defective metabolism, logically then should appear more frequently in males than in females. The high sex ratio of still births, and the estimated higher ratio of intreuterine death in the early months of gestation lend support to the thesis of metabolic differences. The final argument leads us back, however, to genic factors. Riddle[54] places the responsibility for the higher metabolism of the male on the deleterious Y chromosome. All in all, whatever theory one accepts, the final answer seems to reside in a genic constitution.

Left handedness, twinning, stuttering, the high sex ratio: all may have a common denominator in heredity but a description of the heritable factor or factors cannot be given.

No far flung generalization can be made on the basis of this study. We do not advance our thesis as the ultimate explanation of stuttering, for its etiology probably will not be recorded in a few sentences. Indeed, through overstatement and unwarranted claims, much of the research in the past has beclouded rather than clarified the issues. Turgidity too often has been mistaken for profundity. "One does not get nearer to the ideal state any the more quickly by trying to force the shortest cut to the goal of strictest unity, by proclaiming meager be-

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[53] Riddle, Oscar. Factors in the development of sex and secondary sexual characteristics. *Physiological Reviews*: 11: no. 1: 63-106. January 1931.

[54] Riddle, Oscar. *op. cit.* pp. 63-106.

ginnings as the final principles, and by owing to the facts what is saved on the theories."[55] This study represents a meager beginning. Before final principles can be set down, an extensive investigation of twinning families should be made; a similar survey of left handed families should be undertaken. Through such projects one will avoid the pitfall of owing to the facts what is saved on theory. Stuttering then may be nearer a solution.

CONCLUSIONS

1. In a study of 462 stutterers and 500 non-stutterers it was found that twinning occurs more frequently in stuttering families than in non-stuttering families.

2. In stuttering families containing both twins and single siblings, stuttering is more frequent among the twins than the single siblings.

3. Connections previously having been established between left handedness and twinning, and between left handedness and stuttering, a common denominator residing in genic factors is postulated.

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[55] Kohler, W. The Mentality of Apes. Harcourt, Brace and Co. *New York.* 1925.

POPULATION GROWTH IN PALESTINE

BY JONAS S. FRIEDENWALD

THE trends of population growth in Palestine present several unique features. In a small country two culturally distinct groups, with almost complete absence of inter-marriage are growing rapidly in numbers,—one, the Arabs, largely but not exclusively by natural increase, the other, the Jews, largely but not exclusively by immigration. Growth by immigration has not, so far as I know, been the subject of careful enumeration elsewhere, if, in fact, it has ever occurred on so intense a scale within modern recorded history. We are presented, therefore, with an opportunity to study in how far the growth of a population by immigration follows the same laws as those that have been found to hold for growth by natural increase. A priori, it need not be supposed that the growth laws in the two cases should be essentially different, for even with a limitless supply of potential immigrants a barren country can not be densely settled over night. There must be first comers who build roads, drain marshes, found cities, begin industries, and during the early period the absorptive capacity of the country for new immigrants can be expected to depend in large measure on the number already settled. Thus the early stages of population growth by immigration should tend to be logarithmic resembling in this respect the early stages of population growth by natural increase, though the growth rate in the former case may exceed any possible figure in the latter.

The velocity of population growth in Palestine, both for the Jews and the Arabs is, in fact phenomenal, and it appears likely, therefore, that the whole cycle of growth may be completed within a few decades, providing thus a condensed version of the more leisurely course of affairs in other lands.

Accurate censuses have been taken only on two occasions, 1922 and 1931, but annual estimates both by the government and by the Jewish Agency, based on the excess of immigrants and births over emigrants and deaths are available for the intervening and subsequent years. Since the apportionment of funds for public health and education

among the various component groups of the community is based in part on their population ratios, these annual estimates are rather carefully prepared and may be considered reasonably accurate. Estimates of the pre-war population are for the most part quite vague, and should be taken with due reserve.

Racial Characteristics

The Arab population of Palestine is divided into two quite distinct ethnic and cultural groups,—a majority form the settled population, peasants and townsmen, while a minority are migratory herdsmen or Bedouin. The latter are of fairly pure Arab stock, closely related to similar migratory tribes in Transjordan and Arabia. They inhabit mainly the southern portion of Palestine, bordering on the Sinai desert, a region in which Jewish colonization has not, as yet, taken place, and neither their way of life nor their number seems to have been influenced up till now by the modern development of the country.

The settled portion of the native population though culturally and politically allied to the Arab world is by no means of pure Arab race but represents the result of the recurrent military invasions and commercial infiltrations that have crossed and recrossed all the strains native to the eastern end of the Mediterranean. They may perhaps be best described as Levantine. About 7/8 of this group are Moslems, the remainder Christians of the Maronite branch of the Greek Catholic Church. The two groups do not intermarry and while racially similar, the Christian group contains a larger proportion of more recently immigrated Greek, Armenian, and Syrian stock. In the census reports the subdivision "Christians" includes, along with the Maronite Arabs, also members of various European religious orders stationed in Palestine, British Government officials and their households and other non-Jewish Europeans, so that the vital statistics of the group represents a far less accurate picture of the native population than do similar data on Moslems.

There have probably always been some Jews in Palestine but for the past two hundred years a slow stream of pious immigrants has come to the country, mainly elderly individuals who hoped to die there. Modern colonization of Palestine by Jews began in 1878 when a group of some hundred families founded a farming village. The course of growth of this population will be discussed below. The largest groups of immigrants have come from Eastern Europe, mainly Russia and

Poland. Since 1932 there has been a considerable immigration from Germany. Small but steady streams of immigrants have come from oriental countries,—Iraq, Bokhara, Yeman. These groups differ ethnically in considerable degree from the European Jewish immigrants, but intermarriage between these different groups is proceeding rapidly.

TABLE 1

Jewish population of Palestine

July 1919	57,000*
Oct. 1922 (Census)	83,790
July 1923	89,505
1924	94,699
1925	120,559
1926	147,398
1927	147,687
1928	152,000*
1929	156,800*
1930	164,900*
Nov. 1931 (Census)	172,300
July 1932	180,793
1933	209,207
1934	253,700
1935	320,358
1936	370,483

* Jewish Agency Estimates

Pre-war Jewish population

	AGRICULTURAL COLONIES**	NEW YISHUB***
1877	200	400
1897	3475	6950
1909	7890	15780
1914	1500	30000

** Population of agricultural colonies as given by Judisches Lexicon 1930

*** Population of New Yishub estimated as twice that of agricultural colonies

A. Jewish population growth

Estimates of the number of Jews living in Palestine at various intervals since July 1919 are given in Table 1. It is evident from a consideration of these figures that the yearly increase represents roughly a constant proportion of the number of those already present

in the country at any given time. This relationship can best be illustrated by charting the data on a logarithmic scale. Figure 1 illustrates the result of such a method of charting and it is evident from this chart that the growth of the Jewish population has, in fact, followed a steady trend which may be estimated at 11.3 per cent increase per anum. Fluctuations from this constant rate have occurred but at no time has the actual Jewish population been greater or less than that predictable on an estimate of uniform growth rate by an amount which anticipates or lags behind the calculated number by more than twenty months. In view of the fluctuating cycles of prosperity and depression which have occurred in Palestine and in the world at large since 1919, this close agreement between the actual growth and the theoretical growth at a uniform rate is most remarkable.

It is illuminating to compare this post-war growth with the pre-war growth of the same group. Before the World War, Palestine Jewry was divided into two groups,—one, the so-called Old Yishub, consisted in persons who went to the country on account of religious motives and who were supported there by gifts of charity from world Jewry and who had no economic roots in the country. The second, at that time smaller group, the so-called New Yishub, consisted in Zionist colonists who had come to Palestine to build there a permanent home for their people and who established themselves in the agricultural colonies and in the towns as a part of the working, producing community.

The World War resulted in an almost complete dissipation of the Old Yishub. By starvation, by disease, by emigration, and finally by economic absorption into the New Yishub, the Old Yishub ceased to exist. If, therefore, we wish to compare the post-war growth of the community with its pre-war growth, we must consider not the total pre-war Jewish population, but the pre-war population of the New Yishub alone. No direct estimates of the pre-war New Yishub are available but fairly accurate counts of the number of Jewish agricultural colonists were made in the pre-war period, and it is also generally agreed that during the pre-war period, the New Yishub was about equally divided as between agricultural colonists and city dwellers. These estimates for the population of the agricultural colonies and for the total New Yishub are given in Table 1.

From the post-war data of Table 1 and Figure 1, one can compute the expected population of the New Yishub for any pre-war year on

the assumption that the New Yishub had been growing continuously at the same rate as the post-war community and attained the numbers actually found in the post-war period. This may be done most simply by extending downwards and to the left the straight line which has been

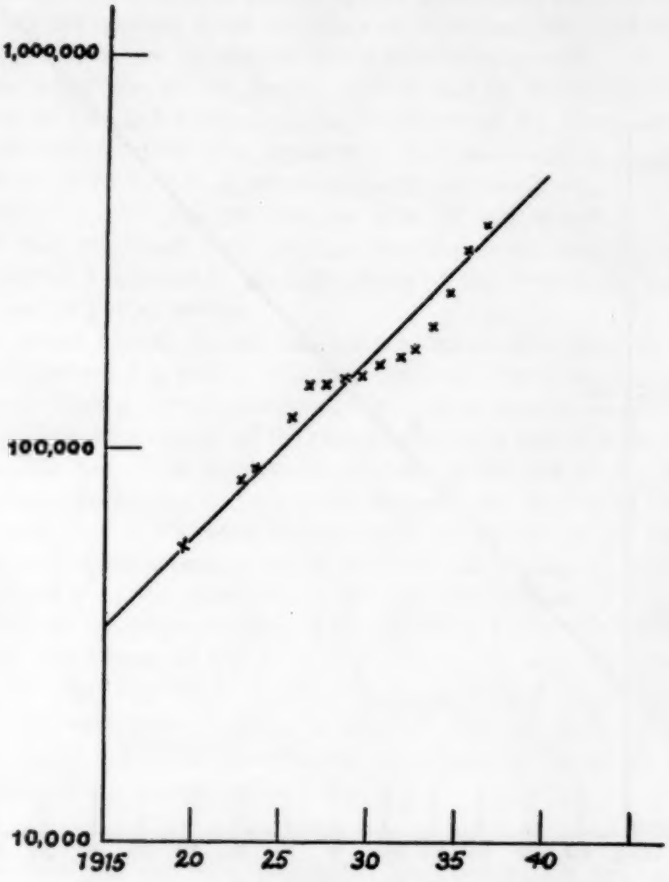

FIG. 1. POST-WAR JEWISH POPULATION OF PALESTINE

drawn through the data plotted on Fig. 1. In Fig. 2 this comparison is made and it is seen that the growth of the pre-war New Yishub is continuous and homogeneous with the post-war growth. Even if it is assumed that there is an error in estimating the population of the New Yishub at twice that of the Jewish colonies, the fact still remains that

the growth rate of the colonies from 1878 to 1914 was uniformly the same as that of the post-war Jewish community.

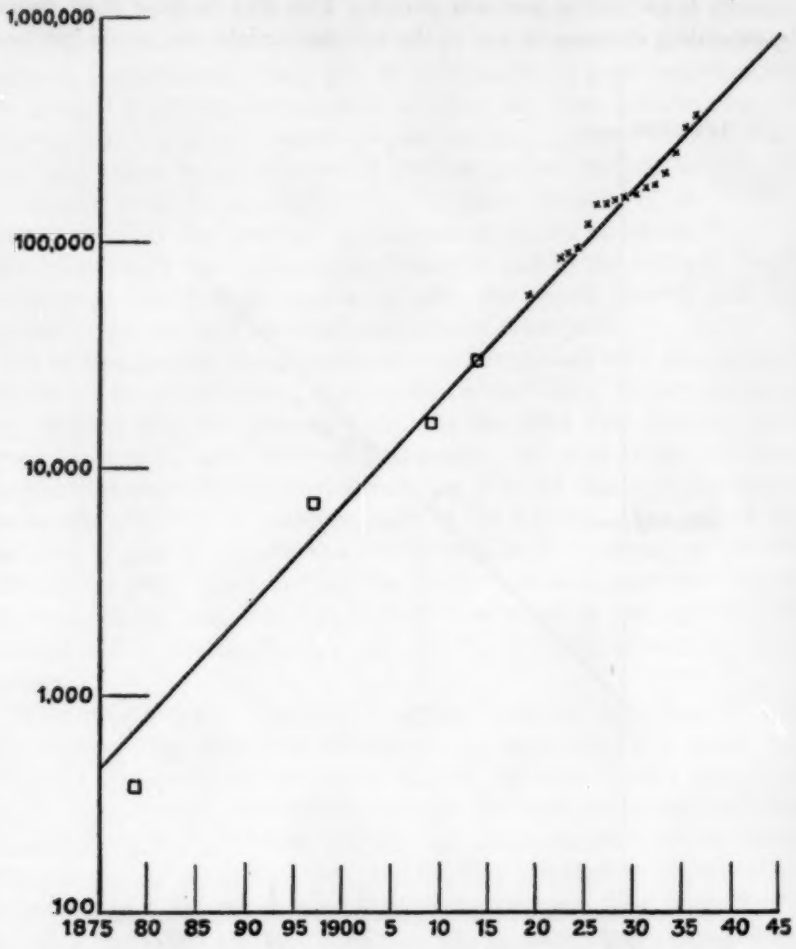

FIG. 2. COMPARISON OF POST-WAR JEWISH POPULATION OF PALESTINE WITH PRE-WAR NUMBERS OF ZIONIST COLONISTS

DISCUSSION

It is apparent that a uniform and continuous growth which has now been maintained for 58 years must be an expression of some fundamental social forces within the community, forces so fundamental that

their operation has been uninfluenced by such major political changes as the shift in sovereignity of the country from the Turkish Empire to that of the Mandatory Power, forces so fundamental that major catastrophies to the world and to the Jewish people, such as the World War, the post-war cycle of prosperity and depression, the Nazi Revolution, and the various Arab uprisings in Palestine, have produced if anything, only minor fluctuations in the population growth.

The magnitude of the Jewish growth rate in Palestine surpasses anything in recorded history. In the settlement of the North American continent where there was apparently limitless available space, and the whole of Europe as a potential source of immigrants, the growth rate never exceded 3½ per cent per year for any decade. That the growth rate of Jewish Palestine has exceeded more than three times this figure is a measure of the adaptability of the Jews to the land and of the land to Jewish settlers.

An annual growth rate of 11.3 per cent results in a doubling of the population every 6½ years. We may conclude, therefore, that, on the average it takes a Jewish immigrant 6-7 years to become so thoroughly absorbed into the economy of the country that he is able to make a place for another Jew. The importance of this for the life of the country may be seen in the fact that six years elapsed from the end of the war, when every one in Palestine had to begin life afresh, to the boom of 1925-6, and again a similar period from the depression of 1926-7 till the beginning of the most recent wave of immigration in 1933.

Owing to the preponderance of young adults among the immigrants the age distribution of the Jewish population is very abnormal, the birth rate relatively large, and the death rate extremely small. The natural increase varies from 2 to 2½ per cent per year. Roughly, therefore, the population growth may be accounted for as ⅘ by immigration, ⅕ by natural increase.

B. Arab population growth

The data for the Arab population are considerably less accurate than those for the Jewish population and far less easy to interpret. There is, however, general agreement that the Arab population is growing at a rate of 2.5 per cent to 3 per cent per year. Thus comparing the censuses of 1922 and 1931, one finds that the settled Moslem and Christian population has increased from 612,000 to 784,000 representing an increase of 2.8 per cent per year, a figure which accords well with the annual excess of recorded births over recorded deaths.

It is extremely difficult to form any idea of the population trends among the Arabs in pre-war times, since only rough estimates are available. It is, however, plain that the total change in the Arab population from the middle of the last century until the pre-war years was very small. Thus the *British Encyclopedia* of 1880 and of 1911 give the figure of 650,000 for the total population of Palestine. Since the Jewish population was increasing somewhat during this period there may have been an actual slight decrease in the number of Arabs.

It is of interest to inquire as to when this stationary population began to increase. Most of those who have discussed this problem have assumed that the beginning of the Arab growth coincided with the establishment of British authority in the country. Mr. Mills in the 1931 census report, however, draws attention to a definite excess of Moslems aged 26-32 in 1931 as compared with those over 32, and points out that this discrepancy could be explained on the supposition that an increase in the birth rate occurred in the years subsequent to 1899 as compared with the birth rate before 1899. Mr. Mills notes that a similarly rising birth rate in the years before the war was noticed in the Census Reports for Bengal 1921, wherein it was suggested that population was in those years preparing unconsciously for the World War. A much more reasonable explanation is that the influence of the Jewish colonization began to make itself felt in an improvement in Arab standards of living in those pre-war years. Not only was there a growing and progressive minded community which gave increasing opportunities to Arab labor and commerce, but also it was in those years that Arab farmers and cultivators in the neighborhood of Jewish agricultural colonies first began to imitate the modern methods of agriculture which the Jews were introducing.

While the present cycle of Arab population growth began, therefore, about the beginning of the century, it cannot have had from the first its present rapid rate. This can be seen as follows. If we compute the settled Arab population on the assumption of a 2.8 per cent annual increase extending backwards in time from the census figure of 1922 we reach 330,000 for 1900, a number which is obviously too low. It is evident, therefore, that while the Jewish growth rate has been uninfluenced by the Arab population and has not been dependent on any opportunities for growth created by the Arabs, the Arab growth rate, on the contrary, has been largely and favorably influenced by the Jewish population, increasing as the Jewish population itself has increased.

Thus the Government estimates of the Arab population showed an increase from 575,000 in October 1922 to 630,000 in July 1927, corresponding to an annual increment of just under 2 per cent during a period when the average Jewish population was 115,000. Similarly, the Government estimates of the same group showed an increase from 784,000 in November 1931 to 897,000 in July 1936 corresponding to an annual increment of 2.75 per cent during a period when the average Jewish population was 275,000. Thus an increase of 150 per cent in the Jewish population at stationary growth rate has been associated with an acceleration of 37 per cent in the Arab growth rate. It must be pointed out that both of the periods compared were periods of economic prosperity for the country; also that while the Government made a correction in its estimate of the Arab population, adding roughly 80,000 to its figure for 1926 to obtain that for 1927 on the well founded assumption that the previous figure gave a short count, still the annual increment was based on the excess of births reported over deaths reported, and this should have made the annual increment appear unduly large during the earlier period when the gross population was underestimated.

This dependence of the Arab growth rate upon the numbers of the Jewish population is well illustrated by the fact that the population of those sub-districts such as Beersheba, Bethlehem, Nablus, and Jenin where practically no Jews have settled, show a smaller rate of increase than does the Arab population of the whole country. It is evident that the Arab growth has followed an approximately logistic form. The data are as yet insufficient to make the attempt of fitting a logistic equation, for the lower assymptote is unknown and the recorded segment of the growth cycle extremely short.

It is somewhat difficult to estimate the relative proportions of natural increase and immigration which contribute to the growth of the Arab population. Fertility is extremely high, but infantile and juvenile death rates are also very great. The excess of reported births over reported deaths would account for a natural increase of about 2½ per cent but the reporting of vital statistics in the country is far from satisfactory. Up to the present no effort has been made to count the number of those, partly seasonal workers, partly permanent settlers, who drift across the borders. By various methods of calculation it may be estimated that not less than 10 per cent, not more than 20 per cent of the Arab increase has been due to immigration.

CONCLUSION

On the basis of the short period of observed growth no predictions for the future seem justifiable. The present effort has been merely to place the available data in a form which will illuminate current trends, and to call attention to those unique features of growth velocity and of the preponderant influence of immigration which make the Palestine population growth of special interest.

DERMATOGLYPHICS IN RWALA BEDOUINS

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THE dermatoglyphics of the Rwala are of special interest because these Arabs represent a relatively pure racial group, isolated by virtue of their nomadic life and the hostility of the desert from the settled populations of the Near East. Furthermore, Shanklin ('35) has shown that the Rwala are very high in blood group **O** (one camp, 79 subjects, 94.9 per cent), while all the other previously studied Near East peoples are relatively low in blood group **O**, Parr ('31). Subsequent blood group studies, by Shanklin, on two other bedouin tribes in the North Syrian desert also reveal a high percentage of group **O**.

The extensive studies of the Krischners ('32) and Kappers ('34) on the cephalic index of Near East populations demonstrate a prevailing brachycephalism; the Rwala in contrast are dolicocephalic and mesocephalic (270 subjects, mean cephalic index 75.00±.103). However, the dolicocephalism of the Rwala bedouin is not surprising for Shanklin ('34) found dolicocephalics and mesocephalics predominating among the nomads and villagers of Transjordania (791 subjects, mean cephalic index 77.3).

The material presented consists of palm prints of 231 Rwala males, mostly adults, and complete finger-print sets of 200 of these subjects. Owing to the great scarcity of water in the Syrian desert and the consequently dirty hands a number of prints were so unsatisfactory that they were discarded. The material was collected from five different camps in some cases more than 100 miles apart.

The prints were collected, interpreted and formulated by Shanklin, after which Cummins carefully reviewed and checked all interpretations and formulations against the prints themselves. The comparative material was prepared by Cummins. The palmar features are interpreted and formulated strictly according to the method of Cummins *et al.* ('29). The Arch-Loop-Whorl classification of Galton for finger prints is used in this study.

DATA

Finger prints. Complete finger-print sets are available for 200 subjects. The frequencies of the pattern types in these 2000 digits are:

Arches, 3.8 per cent
Radial loops, 2.6 per cent
Ulnar loops, 54.6 per cent
Whorls, 39.1 per cent

The mean "index of pattern intensity" is 13.53 ± .17. This index (Cummins and Steggerda, '35) is merely a summation of values assigned as rough measures of the levels of pattern expression: Arches, 0; Loops, 1; Whorls, 2. It will be evident that individual finger-print sets resolve indices ranging from 0 to 20, the figure being with rare exceptions (occasioned by the presence of tented arches and composites having more than two triradii) equivalent to the number of triradii related to the ten patterns. Mean indices in racial collections naturally are confined to the intermediate extent of this range; of all races recorded to date the Efe Pygmies (Dankmeijer, '34) represent the minimum value, 10.32, while Abel's ('33) series of Greenland Eskimos are at the opposite extreme, with the index 17.13.

TABLE 1

Percentile occurrence of pattern types for each digit based on 200 right and 200 left hands, each pair having ten-finger set complete

DIGITS	I		II		III		IV		V	
HANDS	R	L	R	L	R	L	R	L	R	L
Arches	0.5	2.5	9.0	8.5	5.0	9.0	....	2.5	0.5	....
Radial loops	0.5	....	9.5	10.5	1.5	2.5	1.5	....	....	....
Ulnar loops	43.5	51.5	36.0	41.5	70.0	65.0	40.5	48.0	70.5	79.5
Whorls	55.5	46.0	45.5	39.5	23.5	23.5	58.0	49.5	29.0	20.5

Table 1 carries a listing of the pattern frequencies separately for digits and hands, to be available for future comparative use with such methods as the dactylodiagram of Poll.

Palmar main lines. Table 2 lists the terminations of main lines. The essential usefulness of the main-line terminations is derived from their indications of the degree of slant of the general palmar configura-

TABLE 2

Terminations of the palmar main lines, stated in terms of the percentile occurrence of each position.
(Compiled from 230 individuals, the reductions due to indecipherable prints being indicated at the head of each column)

	LINE A		LINE B		LINE C		LINE D	
	(228)	(230)	(227)	(230)	(224)	(224)	(227)	(230)
POSITION	R	L	R	L	R	L	R	L
1	0.4	3.5	....	....	....	....	....	....
2	1.3	6.1	....	....	....	....	....	....
3	29.4	46.5	....	1.3	....	....	....	....
4	18.9	18.7	....	0.4	....	....	....	....
5′	43.0	22.6	2.6	7.4	....	0.4	....	....
5″	6.6	2.2	37.4	54.4	5.4	14.7	....	....
6	0.4	0.4	3.1	4.8	2.2	4.5	....	....
7	....	....	52.9	31.3	25.9	31.7	5.3	14.3
8	....	....	1.3	0.4	0.9	1.8	2.2	4.8
9	....	....	2.6	....	42.0	16.5	31.7	43.5
10	....	....	....	....	1.3	0.4	3.5	4.8
11	....	....	....	....	2.6	....	56.4	31.3
12	....	....	....	....	....	....	0.4	0.4
X	....	....	....	....	2.2	5.4	....	....
x	....	....	....	....	1.3	6.3	....	....
0	....	....	....	....	16.0	18.3	0.4	0.9

tion. Cummins ('36) has proposed a method of converting the formulated main-lines A and D into a "main-line index" which is descriptive of this slant. The index for the Rwala, 8.59 ± .07, indicates moderate transversality of the configurations. The indices derived separately for right and left hands, 9.28 ± .08 and 7.90 ± .09 respectively, reflect the characteristically greater degree of transversality of the right hand.

Axial triradii. Determinations of axial triradii could be made only in 223 right palms and 229 lefts. Combining right and left hands, which is justified by the absence of any significant bimanual differences shown in the tally of these features, the frequencies of the types and their combinations are as follows: t, 77.7 per cent; t′, 13.1 per cent; t″, 1.6 per cent; tt′, 4.0 per cent; tt″(2.7 per cent; t′t″, 0.4 per cent; tt′t″, 0.7 per cent.

Palmar patterns. Percentile frequencies of the five palmar patterns, listed separately for right and left hands, are presented in Table 3.

TABLE 3

Percentile frequencies of palmar patterns

(The figures indicate the occurrence of true patterns and marked pattern vestiges in each of the five palmar areas. Compiled from 230 right hands and 231 lefts)

	RIGHT	LEFT
Hypothenar	31.7	39.0
Thenar/First Interdigital	5.2	11.3
Second Interdigital	8.8	2.6
Third Interdigital	48.2	27.6
Fourth Interdigital	44.7	69.0

Attention may be directed to the differential bimanual occurrence of hypothenar patterns. Hypothenar patterns are more frequent in left hands, a condition which has been reported in Chinese and various collections of American Indians (see Steggerda, Steggerda and Lane, '36), in contrast to the typical "European" trend of a superiority of the right hand.

DISCUSSION

It is not purposed to make extensive comparisons of the Rwala dermatoglyphics with data obtained in all the studies which are now on record, for it is necessary to defer such broad comparisons until more representative racial data are at hand. In the meantime, however, it will be of interest to select for comparison a few peoples of probable relationship to the Rwala, and particularly those whose blood groupings and cephalic indices are similar or in contrast. Such data are at hand in several published studies, and to enlarge the numbers for increased stability of the trends certain unpublished material is added. It may be important to mention that all the formulations in the material now to be considered, excepting the series of 50 Arapaho Indians reported by Downey, were originally made or checked by Cummins. The figures are listed in Table 4, and the sources are explained in the footnotes accompanying it.

Racial resemblances and differences in dermatoglyphic features are made out by comparing the frequencies of their variants: the occurrences of the finger-print types — arches, loops and whorls — together with variations in size, form and digital distribution of these patterns;

TABLE 4

Comparison of finger prints and palmar dermatoglyphics of the Rwala with several peoples

(In the groups for which two numbers of subjects are indicated different totals are available for analysis of the various features [e.g. Rwala — finger prints, 200 subjects; palms, 231])

PEOPLE AND NUMBER OF SUBJECTS	FINGER-PRINT PATTERNS (*per cent*)				MAIN-LINE INDEX	PALMAR PATTERNS (*per cent*)				
	Arches	Radial loops	Ulnar loops	Whorls		Hypothenar	Thenar/first interdigital	Second interdigital	Third interdigital	Fourth interdigital
Rwala (200-231)	3.8	2.6	54.6	39.1	8.59	35.4	8.3	5.7	37.9	56.9
[1] Mitwali (138)	2.7	4.2	50.9	42.2	8.50	31.1	14.1	6.5	57.9	57.6
[2] Lebanese (89-106)	2.5	2.9	49.3	45.4	8.47	37.9	18.8	9.4	57.2	59.0
[3] Jews, New Orleans (200)	4.2	3.0	50.0	42.7	....	40.5	17.7	9.0	52.7	54.0
[4] North-American Indians (361-411)	4.9	2.5	42.0	50.6	6.96	13.6	26.9	1.8	24.8	73.5
[5] Mexican and Central-American Indians (528-633)	4.3	3.1	53.6	38.9	7.47	11.6	40.0	2.3	25.8	65.6
[6] Eskimos (89-117)	3.7	2.0	47.6	46.6	8.20	20.9	13.5	2.2	45.3	57.3

[1] The Mitwali are a Syrian mountain people. Males and females are represented in this collection in the proportion of about two to one, respectively. Cummins and Shanklin, Am. J. Phys. Anthrop., vol. 22, 1937.

[2] Lebanese males, mainly students at the American University of Beirut. The collection contains 89 right hands and 106 lefts; to make the figures here listed comparable to those in ordinary series, which include both hands of all subjects, the frequencies of particular features determined separately for rights and lefts are directly averaged. Unpublished data of Cummins and Shanklin.

[3] New Orleans Jews, 100 males and 100 females. Cummins and Midlo, *Am. J. Phys. Anthrop.*, vol. 10, 1927. The palmar main lines were not formulated by the revised method, and the main-line index thus can not be calculated from the published data.

[4] Pooled figures (weighted averages of the five series) for 50 Arapaho (Downey, *J. Exp. Psychol.*, vol. 10, 1927); 67 Comanche (Cummins and Goldstein, *Am. J.*

the frequencies of patterns, as opposed to patternless configurations, in the five palmar areas; the characteristics of main lines, etc. The present comparisons are limited to the items carried in Table 4.

As yet we do not know how to determine the relative values of the various features. The comparisons must therefore be provisional and of a very general nature, further caution being demanded by the varying sexual composition of the compared series and their limitations in point of numbers.

In introducing the comparisons reference may be made to the conception of primitiveness in the dermatoglyphics. According to prevailing opinion (see especially Wilder, '16) whorls are considered to be the original or primitive configuration. From this viewpoint a people having abundant whorls on the finger tips would be regarded as more primitive, with respect to this feature, than another stock presenting a lower frequency. Likewise in the palm, the presence of patterns in the five configurational areas is commonly believed to be a more primitive state than that when the areas lack patterns. The tendency toward longitudinal alignment of the general palmar configuration is presumably less advanced than the trend toward the transverse. An examination of racial groups discloses that if this conception of primitiveness is correct not all dermatoglyphic features retain their original traits in uniform degree. Keith ('24) devotes some attention to the inverse tendencies of two of the palmar patterns, pointing out that as thenar [together with the associated first interdigital] patterns increase in number the hypothenars diminish. The data presented in our Table 4 not only support this generalization but they show that the fourth interdigital pattern varies in the same direction as the thenar/first interdigital, while the second and third interdigitals are coupled with the hypothenar, in general increasing or decreasing in its company. The inclination of palmar main lines, while showing a less strict conformity, does exhibit a fair degree of association with the frequencies of palmar patterns,

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Phys. Anthrop., vol. 17, 1932); 93 Navajo, 59 Hopi and 130 Pueblo (from unpublished data of Cummins). The sexes are about equal in numbers.

[8] Pooled figures (weighted averages): Cummins, *Am. J. Phys. Anthrop.*, vol. 15, 1930; Leche, Publication No. 5, *Middle American Research Series, Tulane Univ.*, 1933; Leche, *ibid.*, 1936; Cummins, *ibid.*; Cummins and Steggerda, *ibid.* The subjects are mainly males.

[9] Pooled figures (weighted averages): Midlo and Cummins, *Am. J. Phys. Anthrop.*, vol. 16, 1931; Cummins, *ibid.*, vol. 20, 1935. Sixty-nine males, 50 females.

transversality being greater in the groups with less frequent thenar/first interdigital and fourth interdigital patterns and the more abundant hypothenar, second and third interdigital patterns. Patterns of the finger tips appear to have a larger measure of independence from the variants of the palmar features.

To apply the criteria of primitiveness to single cases, two groups may be compared. In the North-American Indians it is found that while the group seems to be primitive in some features (high frequency of whorls on the finger tips, marked tendency toward a longitudinal palmar configuration, relatively frequent thenar/first interdigital and fourth interdigital patterns) in others (infrequent hypothenar and second and third interdigital patterns) it would appear to be more advanced. In contrast, the Rwala are more advanced in the very items wherein the Indians are primitive, while for the three palmar areas noted in the Indians as advanced, signified in lower frequencies of patterns, the Rwala are seemingly more primitive! The solution to this paradox probably lies at least partly in a differential and independent behavior of the various features, but it seems likely that it may be identified also with a false presumption of primitiveness. It may be remarked that the situation is expressed not only in racial variation but also through bimanual differences in the one race (Cummins, Leche and McClure, '31). The trends characterizing right hands in this European-American series are: more frequent apical whorls; greater transversality; more abundant hypothenar, second and third interdigital patterns; less abundant thenar and fourth interdigital patterns. Sexual differences in the same collection are nearly a parallel, males displaying essentially the same contrasts with females as do right hands in comparison with lefts. But since we are at present concerned merely with racial comparisons, and not with an attempt to trace the origins of the peoples, the matter of primitive characteristics need not be followed further.

Table 4 is divided into two sections, the first embracing the Rwala, Mitwali, Lebanese and Jews in America. These four peoples exhibit a close relationship, but among them the most marked distinctions occur in the Rwala. The three Pacific American populations contained in the second division of the table exhibit various traits in common. The Eskimos are perhaps the most distinctive, considering all features, and it should be noted that of the three their relationship is the most close to the trends in the groups above, and of these especially to the Rwala.

An independence of blood groups and dermatoglyphic traits is suggested by this comparison. The Indians and Eskimos, with an expected high frequency of **O**, appear to be less closely allied to the Rwala than are the two Near East peoples and Jews, who have a much lower frequency of this blood group. The Indian and Eskimo subjects of these particular collections are of unknown blood groups, and reliance must be placed on observations in other samples; in spite of this, it is obvious that an exceptional incidence of blood groups in these series would be insignificant, since the resemblance of the Rwala to the Near East peoples and Jews contraindicates the assumption of a correlation between blood groups and dermatoglyphics. (For further discussion of the question of finger print and blood group correlation see: Hesch, *Zeitschr. f. Rassenphysiol.*, vol. 5, 1932; Geipel, *ibid.*, vol. 7, 1935; Blotevogel, H. and W., *Zeitschr. f. Kinderheilk.*, vol. 56, 1934.)

Turning now to the question of whether cephalic index and dermatoglyphics may be associated, it will be recalled that the Rwala are prevailingly dolicocephalic; the peoples with whom they are here compared are mesocephalic and brachycephalic. The indications of the data are that cephalic index and dermatoglyphics vary independently. Thus, though the Indians and Eskimos differ markedly from the Rwala in their dermatoglyphics, it is apparent that such differences are not linked with the cephalic index inasmuch as the Mitwali, Lebanese and Jews are closely related to the Rwala notwithstanding their differing trend in cephalic index. This finding is not entirely unexpected, Cummins and Steggerda ('36) having already reported, in reference to Maya and Dutch series, the lack of significant correlation between the cephalic index and finger-print traits (as expressed in the index of pattern intensity, pattern size and pattern form).

SUMMARY

The dermatoglyphics of 231 Rwala Arabs are analyzed, with the following key findings. Among finger-tip patterns whorls are of moderate frequency, 39.1 per cent. A fairly marked degree of transversality of the general palmar configuration is indicated in the main-line index, mean 8.59. The frequencies of palmar patterns are: hypothenar, 35.4 per cent; thenar/first interdigital, 8.3 per cent; second interdigital, 5.7 per cent; third interdigital, 37.9 per cent; fourth interdigital, 56.9 per cent.

These characteristics are in close keeping with two other Near East peoples for which data are available, the Mitwali and Lebanese, as well as with Jews. Comparisons are drawn also with North American Indians, Mexican and Central American Indians, and Eskimos. The dermatoglyphics in these groups are distinctive from the Rwala, though of the three the Eskimos present the most close relationship. The similarities and differences of the groups here compared suggest that dermatoglyphics vary independently of both cephalic index and frequency of blood group **O**.

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THE TRANSVERSE GROWTH OF THE EXTREMITIES: AN ANALYSIS OF GIRTH MEASUREMENTS FOR ARM, FOREARM, THIGH, AND LEG TAKEN ON IOWA CITY WHITE CHILDREN

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PURPOSE

The general purpose of this study is to give an objective description of the postnatal growth of white children with respect to four measurements of limb girth. Specifically, the aims of the investigation are (1) to compute central tendency and variability values for circumference of arm, forearm, thigh, and leg at thirty-one successive age intervals between birth and eighteen years, (2) to calculate percentage increment series based on the means for each sex in each measurement, (3) to analyze the transverse growth of the limbs with reference to age trends, sex differences, and individual variations, and (4) to compare growth of the extremities in circumference with other selected body dimensions.

ANGLO-AMERICAN LITERATURE

The earliest of the British and American investigators found to have published quantitative findings for limb girths of white children were Fergus and Rodwell (5). In 1874 these authors reported an anthropometric study of 550 English schoolboys ranging in age between ten and nineteen years. Included among the series of measurements taken were (1) "girth of the flexed arm, measured at the broadest portion of the biceps muscle near the shoulder, the muscle being at rest," and (2) "girth of the leg measured at the broadest portion of the calf" (5, p. 126). The paper gave no analysis of these data beyond statements to the effect that, for the entire sample, arm girths were found to range from 16.5 to 30.0 cm. and girths of leg from 24.7 to 41.2 cm. The study was made at Marlborough College, England.

Six years later, the Anthropometric Committee of the British Association for the Advancement of Science (4) incorporated in its report a study based on 1,850 observations each for circumference of arm and circumference of leg. These

observations represented a cumulative extension of the earlier study by Fergus and Rodwell in that they covered the same age span and were "made during several years by Doctor Fergus on boys in Marlborough College" (4, p. 147). In measurement of the upper extremity "the arm was held in a loosely-flexed state, the muscles being at rest and flaccid; the measurement being made around the thickest part of the biceps muscle" (4, p. 155). The lower extremity was measured "at the thickest part of the calf, the muscles being at rest" (4, p. 156). Both arm and leg were bared before measurement. A table for each girth gave the frequency distributions obtained at successive annual intervals, together with the averages derived from each distribution. The former showed the degree of individual variation, e.g. the eighteen-year-old boys with the smallest arm and leg circumferences were shown to be exceeded in these dimensions by the eleven-year-old boys with the largest circumferences. The average values obtained, following conversion from inches to centimeters, are reproduced below:

Mean Age, Years	*Observations*	*Arm Girth*	*Leg Girth*
		Centimeters	
11½	89	19.2	27.2
12½	219	19.6	27.9
13½	333	20.3	28.7
14½	370	21.2	29.6
15½	320	22.3	30.7
16½	282	23.8	32.1
17½	150	24.6	33.0
18½	61	25.7	33.8

In 1889, Sargent (13) published a non-technical discussion of results from an anthropometric study made on 1,200 boys and girls of "the student class." The subjects were between thirteen and sixteen years of age and gave a mean age of fifteen years. Two findings for girth measurements of the extremities were reported. The average girth of the right arm for boys was found to be 0.5 cm. larger than the average girth of the left arm, while in girls the arm girth averages for the two limbs were "the same size." The thigh girth of girls was found to exceed that of boys by 5.0 cm. at fifteen years of age. Sargent noted that thigh girth was "the only measurement of women which actually exceeds that of man from the age of thirteen onward" (13, p. 177). The measurement technique used was not described. [This was probably as given in Seaver (15, p. 47).] No tables were included.

At a meeting of the Anthropological Institute of Great Britain and Ireland, held March, 1895, Hall (7) reported an analysis of girth measurements for arm, forearm, thigh and leg. His data were approximately 2,000 observations for each girth taken on "school boys and students of Philadelphia and suburbs" during the previous six years. They covered the age period from nine to twenty years. With few exceptions the subjects were sons of well-to-do American-born parents of English stock. The measurements were made upon the nude body by means of a waxed linen tape. The tape was applied at the greatest diameter of each limb

segment and care was taken to maintain a uniform degree of tension throughout. Median values, based on one-year age groupings, were obtained for each of the four measurements. These follow:

Mean Age, Years	*Observations*	*Arm Girth*	*Forearm Girth*	*Thigh Girth*	*Leg Girth*
			Centimeters		
9½	93	18.7	17.6	37.1	24.7
10½	122	19.8	18.6	39.1	26.1
11½	132	20.4	19.2	40.1	26.8
12½	143	21.3	20.1	41.0	27.7
13½	203	22.5	21.0	42.5	28.8
14½	209	23.9	22.2	44.5	30.1
15½	233	25.5	23.7	46.1	31.6
16½	284	27.3	24.7	48.9	33.4
17½	290	28.7	25.4	50.9	34.5
18½	240	29.7	26.0	51.6	35.1
19½	155	30.3	26.4	52.0	35.4

In 1896, Mrs. Hall (8) published limb girth measurements for a single male infant during the age interval from one to eighteen months. The child's parents were professional people of English-American stock. The measurement values obtained at one, six, twelve and eighteen months were as tabulated below:

Age, Months	*Arm Girth*	*Forearm Girth*	*Thigh Girth*	*Leg Girth*
		Centimeters		
1	10.3	10.3	16.0	12.2
6	13.0	12.7	22.0	15.7
12	15.8	14.7	27.5	19.3
18	16.3	15.5	27.5	19.8

A study by Moon (12) on boys of the McDonogh School, near Baltimore, Maryland, was also published in 1896. The data were gathered from annual measurements over an eight-year period and fell within the age limits of eleven to seventeen years. There was no mention of such items as method of measurement or racial selection of sample. Six tables gave calculated values for circumference of arm, forearm, thigh and leg at five point intervals between the 5th and 95th percentiles. The median or 50th percentile figures from these tables are as follows:

Mean Age, Years	*Observations*	*Arm Girth*	*Forearm Girth*	*Thigh Girth*	*Leg Girth*
			Centimeters		
11½	100	20.2	19.6	38.3	26.8
12½	120	21.0	20.1	39.5	27.7
13½	115	21.0	20.4	40.6	28.3
14½	150	22.4	21.4	42.3	29.8
15½	150	24.4	23.0	44.7	31.7
16½	130	26.2	24.2	46.4	32.5

In 1902 Bjelke-Petersen (1) made a study of the transverse growth of the extremities on male children at Hobart, Australia. Right and left limbs of fifty boys at each age from eight to fifteen years were measured. Central tendency analysis for yearly age groupings showed the right arm and forearm girths to be slightly and consistently larger than the arm and forearm girths of the left side. No consistent differences were found for the right and left girths of the thigh or leg.

Seaver (15) summarized the limb girth research on American college men and women to 1909. He gave central tendency values for male students (average age, twenty years) at Amherst, Cornell, Washington and Jefferson, Wisconsin, and Yale, and for female students (average age, nineteen years) at Nebraska, Oberlin and Wellesley.

At each college the averages (means or medians) for arm, forearm, thigh and leg were found to be slightly higher for the right side of the body than for the left. For the left side, the male averages from the different colleges ranged between 24.8 and 25.8 cm. for arm, 25.8 and 26.1 cm. for forearm, 50.1 and 52.2 cm. for thigh, 33.9 and 35.0 cm. for leg. Corresponding averages for the females ranged from 22.6 to 26.4 cm. for arm, 21.6 to 22.6 cm. for forearm, 53.1 to 55.1 cm. for thigh, and 32.0 to 33.8 cm. for leg. Males thus consistently exceeded females in forearm and leg girths, whereas they were exceeded by females in circumference of thigh.

In 1925 Hrdlička (9) reported an analysis of data for maximum circumference of the left leg accumulated between 1910 and 1924 from measurement of 194 adult males and 64 adult females. The subjects were "Old Americans" (American whites whose parents and four grand-parents were born in the United States) of the clerical-professional classes. It was estimated that no less than 80 per cent. of the subjects were descended from the peoples of Great Britain and Ireland. They ranged in age between approximately 22 and 60 years of age. Measurements were made with the left foot so placed on a bench that the leg formed slightly more than a right angle with the thigh and the leg muscles were relaxed. Readings were taken with the anthropometric tape "snugly around the leg but not tightly enough to cause an impression." Obtained averages were 36.1 cm. for males and 35.5 cm. for females. The male observations ranged between 30.2 cm. and 45.3 cm., the female observations between 30.7 cm. and 43.4 cm. Hrdlička concluded: "The mean values of the measurement as well as its distribution are closely alike, so that it may be said the legs in the male and female Old Americans are practically equal, though in the female they contain more fat, in the male more muscle" (9, p. 344). Additional findings, obtained by variously subdividing the data, were: "The leg reaches its optimum development, on the average, in men at thirty, in women after forty" (9, p. 349). "The tall of both sexes have absolutely the stouter legs. Relatively to stature, however, the short have more calf than the tall" (9, p. 347).

An investigation of growth in a large series of external dimensions during the fetal period was published by Scammon and Calkins (14) in 1929. The subjects were well-preserved Caucasion fetuses, undifferentiated as to sex. Circumference of arm was "taken at the level of the greatest thickness of the arm below the insertion of the deltoid muscle" (14, p. 225); forearm and leg girths were made at

"the maximum circumferences" of the respective segments; and "circumference of the thigh was measured just below the gluteal sulcus in the horizontal plane" (14, p. 247). The authors note that all measurements were taken on the right limbs and that "a very slight uniform pressure was used in taking all circumferences for the purpose of removing any slack in the measuring tape and at the same time avoiding any compression of the part" (14, p. 8). Girth means at birth, calculated from empirical equations, were given as 8.9, 9.0, 14.3 and 10.0 cm. for arm, forearm, thigh and leg, respectively.

In 1929 Franzen (6) reported means for arm and leg girths taken on ten-year-old school children—909 girls and 788 boys. Leg girth was measured at the largest part of the bare calf with the leg hanging relaxed. Arm girth was determined over the biceps muscle with the upper extremity in two positions: (1) flexed, the tips of the subject's fingers touching his shoulder with the arm muscles relaxed as much as the position would allow; and (2) extended, the limb hanging loosely at the side of the body. The recorded arm circumference represented an average of the two measurements. The girths were taken with a steel tape having a Gulick spring handle and sufficient tension applied to cause the mark on the plunger to appear. Obtained means for circumference of the right arm were 19.4 cm. for both boys and girls. The leg circumference means were 27.8 cm. for girls and 27.4 cm. for boys.

A study giving girth means for arm and leg of ten-year-old Porto Rican children (902 females and 879 males) was reported by Mitchell (11) in 1932. The same measurement technique as used by Franzen was employed. The obtained means were slightly lower for Porto Rican boys than girls and were below the means secured by Franzen for children of the United States by 2.0 cm. for arm girth and 2.5 cm. for girth of leg. Additional findings of Mitchell were that Porto Rican private school children exceeded public school children, and urban children exceeded rural children, in mean circumference of arm and leg.

In 1932 Bowles (2) published an analysis of measurement data for girths of arm, forearm, thigh and leg taken on college men and women. The data on males were accumulated at Harvard University between 1870 and 1917, while the data for females were collected from four eastern women's colleges. Both samplings were considered to represent North European stock and the professional-managerial class. Method of measurement was not discussed. College women were found to exceed college men in thigh girth and to be exceeded by college men in the remaining three girths. Harvard fathers (men who later had sons in attendance at Harvard) were found to have smaller mean limb circumferences throughout than had their sons. These findings may be verified from the following tabulation:

Sample	*Observations*	*Mean Age, Years*	*Arm Girth*	*Forearm Girth*	*Thigh Girth*	*Leg Girth*
				Centimeters		
College women.....	372	18.8	25.9	22.2	54.1	33.3
Harvard fathers.....	395	19.7	29.4	25.8	52.1	35.1
Harvard sons.....	478	18.5	30.8	26.8	53.9	35.6

The literature reviewed above shows wide gaps in our anthropometric knowledge of the transverse growth of the extremities between birth

and eighteen years of age. It appears that not a single investigation, for males or females, has been reported covering the age period from two to eight years and that but sparse study of females has been made at any age.

DATA

The data of the present investigation consist of 2,373 measurement values each for arm, forearm, thigh, and leg girth on 771 Iowa City white females and 2,897 measurement values each for like dimensions on 1,013 Iowa City white males. These data were obtained from physical measurement records made at the University of Iowa infant laboratories, preschool laboratories, elementary school, and high school. They represent observations accumulated during the five-year period from 1930 through 1935 by the anthropometric staff of the Iowa Child Welfare Research Station. The records were taken from the files in serial order and all limb circumference readings were accepted for tabulation unless marked as applying (1) to individuals of Negroid or Mongoloid races or (2) to white individuals appearing to lie outside the normal zone for physical build.

Information on country of birth of the parents and on occupation of the father is available for approximately 50 per cent of the subjects. Analysis of the material for these items yielded the following tabulations:

Country of birth of parents

	Per cent	
	Males	*Females*
One or both parents born in:		
United States	95	97
British Isles or Canada	5	3
North European countries	3	4
South Europe (including Russian Jews)	2	1
Both parents born in United States	90	93

Occupation of father

	Per cent	
	Males	*Females*
Professional (mainly members of university faculty)	36	33
Business proprietors, managers, salesmen	23	24
Skilled trade employees	14	14
Farmers	14	16
Clerks, carriers, etc.	10	8
Laborers	3	5

It is evident from these figures that in addition to being homogeneous with respect to geographic location the sample of white children employed represents a population that is predominantly composed of the professional and managerial classes and is almost entirely of North European ancestry.

TECHNIQUE OF MEASUREMENT

Position of subject. Children too young to assume a standing position were supported by an assistant in positions varying between supine and erect (depending on the development of the infant). The anthropometrist considered an extremity to be in readiness for measurement when it was extended approximately parallel with the long axis of the trunk and when its musculature was relatively relaxed. Subjects beyond two years of age were measured in the erect position. The upper extremities hung at the sides of the body in a relaxed condition. The feet were spread about 6 inches apart and the body weight was equally distributed on the lower extremities.

Instrument. A steel millimeter tape was employed in measurement of each of the four limb circumferences. The tape was applied with sufficient tension to make firm contact with the skin and yet avoid compression of the tissues.

Area of Measurement. All measurements were made on the left extremities of the body except those for newborn infants. The newborns[1] were necessarily measured on the right side since they were vaccinated on the left.

Arm circumference was measured near the middle of the humerus, at the level of the greatest girth bisecting the biceps muscle and below the insertion of the deltoid muscle. Circumference of forearm was taken at the level of the greatest girth immediately below the elbow joint.

Measurement of thigh girth was made just below the gluteal sulcus and approximately in the horizontal plane. Girth of leg was measured at the maximum circumference of the calf and roughly at right angles to the vertical plane. All readings for both upper and lower extremities were taken on the nude limb.

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[1] A group of fifty males and fifty females measured between twenty-four and forty-eight hours following delivery.

Dimensional Findings

Central tendency

Tables 1 to 8 give means[2] for each of the four limb circumferences specified with reference to sex, at frequent age intervals between birth and eighteen years of age. Examination of these eight series of means for Iowa City children shows:

1. The two girths of the upper extremity are smaller than either of those of the lower extremity for both males and females throughout the entire age period studied.

2. For females, forearm girth exceeds arm girth between birth and four years of age. At five years of age the two girths are identical, and from six to eighteen years forearm girth is exceeded by arm girth. For males, forearm girth exceeds arm girth between birth and seven years and again between thirteen and sixteen years of age. At eight years of age the obtained means for the two girths are identical. It is a commonplace that thigh girth is larger than leg girth at all ages from birth to eighteen years.

3. The forearm circumference of females is less than the forearm circumference of males throughout the entire age period studied. In contrast, thigh circumference of females is greater than thigh circumference of males during the age span from two and one-half years to eighteen years. Marked sex differences are not evident for girths of arm or leg until around eleven years of age. From the twelfth through the fourteenth years females exceed males in both these dimensions. Beyond sixteen years males decidedly exceed females in mean magnitude of arm and leg girth. (See central tendency curves, Figures 1 to 4.)

The following tabulation illustrates findings which accrue when each series of means is referred to its respective value at birth (*i.e.* the mean at two days of postnatal age). The ages at which birth size is doubled and the percentage increases between birth and eighteen years of age are given.

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[2] The means were calculated as the sum of the measurement values within a given age interval divided by their number. This procedure was followed since the authors consider it advisable to eliminate the error of grouping from means which are intended to be used for obtaining percentage increments. The standard deviations and standard errors of the mean given in Tables 1 to 8 were derived, as is customary, from frequency distributions.

Measurement	*Birth size doubled Age (years)*		*Percentage Increase*	
	Females	Males	Females	Males
Forearm girth	12	11	127	155
Arm girth	10	10	153	167
Thigh girth	5	5½	223	220
Leg girth	4	5	208	220

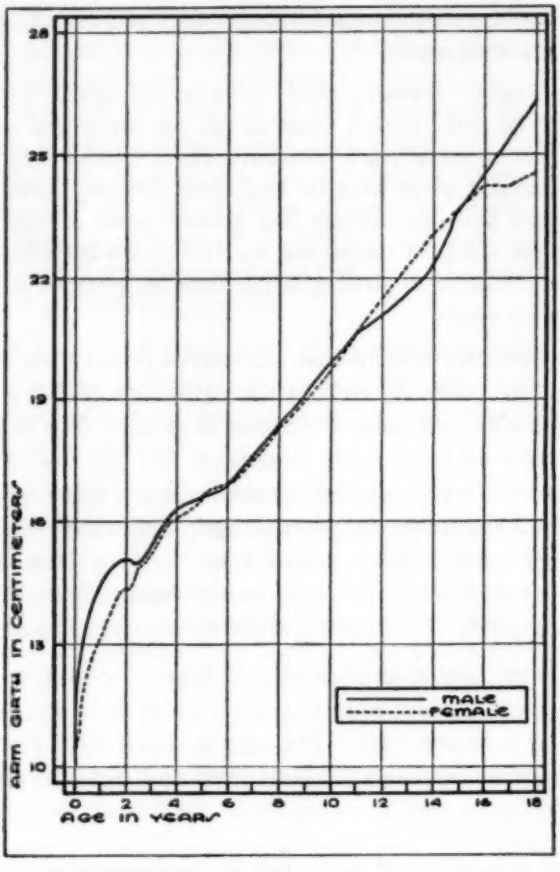

FIG. 1. CURVES OF CENTRAL TENDENCY ILLUSTRATING THE MEAN GROWTH OF IOWA CITY CHILDREN IN CIRCUMFERENCE OF ARM.

Tables 1 and 2 give the series of means to which these trends were drawn

TABLE 1

Arm girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white females, covering the age period from birth to eighteen years

MEAN AGE GROUPING			CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. (Per cent)	RANGE
Year	*Month*	*Day*						
0	0	2	50	9.61	.58	.58	6.0	8.5 to 10.9
0	3	0	42	11.50	.21	1.40	12.1	7.5 to 14.5
0	6	0	86	12.92	.14	1.26	9.7	10.4 to 16.8
0	9	0	96	13.29	.10	1.01	7.6	11.6 to 16.3
1	0	0	94	13.81	.11	1.08	7.9	11.6 to 16.5
1	3	0	78	14.04	.14	1.20	8.5	11.6 to 18.3
1	6	0	68	14.21	.12	.97	6.8	12.5 to 16.3
1	9	0	57	14.30	.13	.95	6.6	12.1 to 16.2
2	0	0	53	14.44	.12	.87	6.0	12.7 to 16.7
2	3	0	44	14.52	.13	.87	5.9	12.7 to 16.3
2	6	0	40	14.88	.16	.98	6.6	13.1 to 17.1
2	9	0	39	15.01	.16	.98	6.5	12.5 to 16.5
3	0	0	41	15.29	.16	1.01	6.6	13.5 to 18.0
3	6	0	53	15.82	.14	1.04	6.6	13.9 to 18.5
4	0	0	54	16.19	.12	.91	5.6	14.5 to 18.4
4	6	0	60	16.23	.14	1.07	6.6	14.0 to 18.8
5	0	0	92	16.44	.11	1.09	6.7	14.2 to 19.8
5	6	0	88	16.74	.15	1.44	8.6	14.6 to 23.2
6	0	0	77	16.90	.15	1.25	7.4	14.8 to 22.9
7	0	0	82	17.54	.19	1.70	9.6	15.0 to 25.0
8	0	0	71	18.43	.24	2.01	10.9	14.0 to 24.2
9	0	0	86	18.99	.22	2.08	10.9	14.5 to 24.6
10	0	0	90	19.62	.22	2.09	10.6	15.0 to 25.1
11	0	0	85	20.51	.22	1.99	9.5	16.6 to 25.1
12	0	0	95	21.43	.22	2.18	10.4	17.0 to 27.3
13	0	0	104	22.32	.24	2.46	11.0	17.3 to 31.0
14	0	0	123	23.27	.25	2.77	11.8	17.6 to 32.5
15	0	0	133	23.84	.28	3.18	13.3	18.6 to 36.0
16	0	0	124	24.23	.25	2.79	11.5	19.2 to 35.5
17	0	0	96	24.17	.26	2.52	10.4	18.8 to 34.1
18	0	0	73	24.34	.28	2.40	9.8	20.2 to 34.4

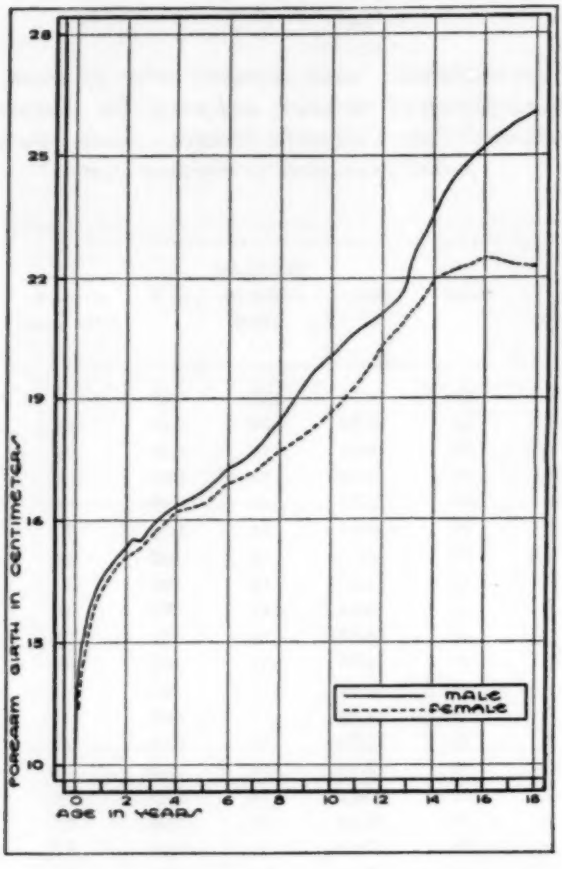

FIG. 2. MEAN MAGNITUDE CURVES FOR FOREARM GIRTH OF IOWA CITY WHITE CHILDREN.

The values on which the graph is based are given in Tables 3 and 4

Considering the means obtained at eighteen years of age as "maturity" values, it is found that arm and forearm girths for both males and females attain 50 per cent of their adult size by the close of the first six months following birth. A like percentage of maturity for circumference of leg is reached by one year of age and for circumference of thigh by one and one-half years.

TABLE 2

Arm girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white males, covering the age period from birth to eighteen years

MEAN AGE GROUPING			CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. (Per cent)	RANGE
Year	*Month*	*Day*						
0	0	2	50	9.90	.12	.82	8.3	8.5 to 11.4
0	3	0	61	12.28	.14	1.09	8.9	9.4 to 15.0
0	6	0	104	13.43	.12	1.18	8.8	11.0 to 16.0
0	9	0	129	14.07	.10	1.10	7.9	11.4 to 16.5
1	0	0	135	14.39	.10	1.16	8.0	12.0 to 17.4
1	3	0	123	14.43	.10	1.14	7.9	12.0 to 17.9
1	6	0	102	14.62	.11	1.07	7.3	12.2 to 17.1
1	9	0	95	14.73	.11	1.06	7.2	12.7 to 17.3
2	0	0	91	15.03	.11	1.07	7.1	12.9 to 17.7
2	3	0	91	15.24	.12	1.13	7.4	12.8 to 18.4
2	6	0	81	15.07	.11	1.03	6.8	12.4 to 17.5
2	9	0	85	15.27	.11	1.00	6.6	12.5 to 17.8
3	0	0	68	15.58	.12	.97	6.2	13.9 to 17.6
3	6	0	91	16.08	.11	1.02	6.3	14.1 to 19.0
4	0	0	98	16.29	.11	1.04	6.4	14.0 to 18.6
4	6	0	91	16.43	.12	1.10	6.7	13.9 to 18.7
5	0	0	98	16.46	.10	.98	5.9	14.6 to 19.8
5	6	0	108	16.62	.12	1.24	7.5	14.1 to 20.3
6	0	0	93	17.08	.15	1.40	8.2	13.8 to 23.0
7	0	0	102	17.69	.17	1.68	9.5	14.0 to 25.0
8	0	0	93	18.45	.18	1.73	9.4	15.2 to 24.1
9	0	0	91	19.28	.21	2.05	10.6	16.0 to 26.8
10	0	0	78	19.80	.22	1.97	10.0	15.6 to 27.5
11	0	0	72	20.58	.27	2.32	11.3	17.0 to 28.2
12	0	0	70	20.99	.25	2.13	10.2	15.8 to 27.3
13	0	0	83	21.51	.24	2.23	10.4	16.9 to 28.2
14	0	0	93	22.48	.24	2.29	10.2	17.7 to 29.0
15	0	0	106	23.88	.22	2.23	9.3	18.5 to 32.2
16	0	0	115	24.71	.19	2.07	8.4	19.2 to 31.3
17	0	0	118	25.64	.24	2.60	10.1	19.0 to 32.5
18	0	0	82	26.39	.28	2.56	9.7	18.5 to 35.0

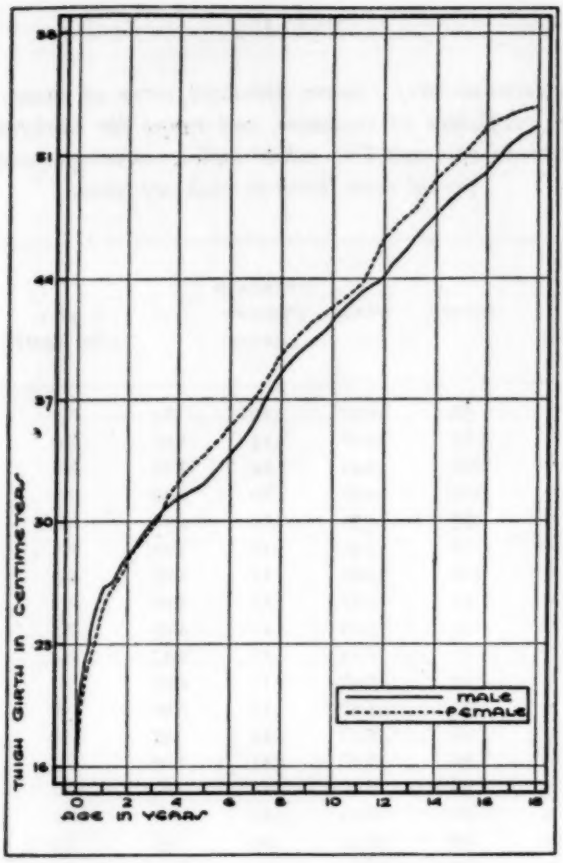

FIG. 3. CENTRAL TENDENCY PLOTS FOR THIGH CIRCUMFERENCE OF IOWA CITY MALES AND FEMALES.

The series of means to which these curves were drawn are shown in Tables 5 and 6.

Variability

At all ages and for both sexes, the standard deviations are least for forearm, intermediate for arm and leg, and greatest for thigh. Consistent characteristics of the standard deviation series are minimal values during the third and fourth years following birth and maximal values around fourteen to fifteen years for females and thirteen to eighteen years for males.

TABLE 3

Forearm girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white females, covering the age period from birth to eighteen years

MEAN AGE GROUPING			CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. (Per cent)	RANGE
Year	*Month*	*Day*						
0	0	2	50	9.86	.07	.53	5.3	8.7 to 10.9
0	3	0	41	11.62	.19	1.21	10.4	7.8 to 14.7
0	6	0	86	13.23	.12	1.12	8.4	10.6 to 15.7
0	9	0	96	13.61	.08	.82	5.9	11.6 to 15.6
1	0	0	94	14.00	.10	.96	6.8	11.6 to 16.5
1	3	0	78	14.21	.11	1.00	7.0	12.1 to 18.2
1	6	0	68	14.36	.10	.83	5.7	12.5 to 16.0
1	9	0	57	14.62	.11	.81	5.5	12.9 to 16.3
2	0	0	53	14.66	.12	.84	5.7	13.0 to 16.9
2	3	0	44	14.78	.11	.71	4.7	13.3 to 16.2
2	6	0	40	15.01	.12	.72	4.8	13.5 to 16.4
2	9	0	39	15.26	.13	.82	5.3	13.5 to 16.8
3	0	0	41	15.40	.13	.81	5.2	13.7 to 17.2
3	6	0	53	15.92	.11	.77	4.8	14.3 to 17.7
4	0	0	54	16.25	.12	.85	5.2	14.5 to 17.9
4	6	0	60	16.25	.13	.96	5.9	13.8 to 18.0
5	0	0	92	16.44	.10	.92	5.6	14.3 to 18.7
5	6	0	88	16.75	.12	1.12	6.7	15.0 to 22.7
6	0	0	76	16.86	.13	1.18	7.0	15.2 to 23.6
7	0	0	82	17.29	.14	1.24	7.1	15.0 to 23.4
8	0	0	71	17.91	.18	1.54	8.5	15.0 to 23.5
9	0	0	86	18.36	.15	1.44	7.8	15.8 to 22.7
10	0	0	90	18.83	.15	1.38	7.3	15.8 to 22.3
11	0	0	85	19.48	.15	1.36	7.0	16.4 to 22.8
12	0	0	96	20.43	.16	1.59	7.8	17.0 to 24.5
13	0	0	104	21.00	.15	1.53	7.3	18.0 to 25.5
14	0	0	123	21.87	.19	2.14	9.8	18.4 to 36.5
15	0	0	133	22.33	.18	2.08	9.3	18.3 to 29.1
16	0	0	124	22.58	.16	1.74	7.7	20.0 to 29.7
17	0	0	96	22.43	.16	1.54	6.8	18.8 to 29.0
18	0	0	73	22.43	.18	1.53	6.8	20.2 to 29.3

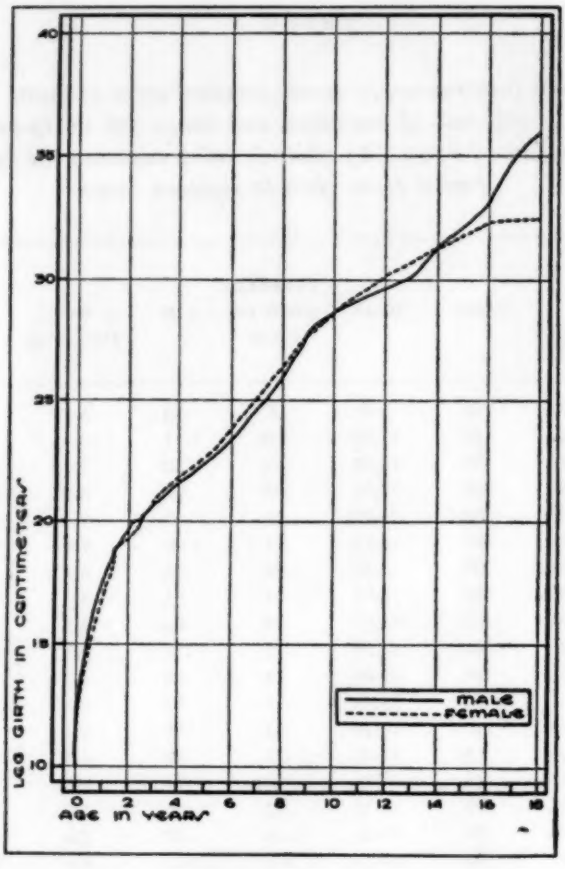

FIG. 4. CURVES OF CENTRAL TENDENCY ILLUSTRATING THE MEAN GROWTH OF IOWA CITY CHILDREN IN CIRCUMFERENCE OF LEG.

Tables 7 and 8 respectively give the series of means to which these trends were drawn.

The minimum value of each series of coefficients of variation for the limb girths of females occurs between two and four years of age. Corresponding minima for the four male limb circumferences are found between three and five years of age. Maxima occur at three to six months of age for both sexes and at approximately eleven years for males and fifteen years for females. For each sex, the minimum

TABLE 4

Forearm girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white males, covering the age period from birth to eighteen years

MEAN AGE GROUPING								
Year	*Month*	*Day*	CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. *(Per cent)*	RANGE
0	0	2	50	10.14	.10	.72	7.1	8.6 to 11.7
0	3	0	61	12.48	.13	1.05	8.4	10.0 to 15.0
0	6	0	104	13.74	.10	1.03	7.5	11.1 to 16.6
0	9	0	129	14.28	.08	.95	6.7	12.2 to 16.8
1	0	0	135	14.56	.08	.95	6.5	12.5 to 17.1
1	3	0	123	14.67	.08	.94	6.4	12.9 to 17.3
1	6	0	102	14.80	.09	.88	6.0	13.0 to 17.1
1	9	0	95	14.96	.10	.93	6.2	13.0 to 17.0
2	0	0	91	15.18	.10	.92	6.0	13.3 to 17.5
2	3	0	91	15.36	.10	.95	6.2	13.6 to 17.7
2	6	0	81	15.27	.10	.86	5.6	13.3 to 17.2
2	9	0	85	15.57	.09	.82	5.2	13.9 to 17.4
3	0	0	68	15.84	.09	.75	4.7	14.3 to 17.7
3	6	0	91	16.24	.09	.82	5.1	14.6 to 19.0
4	0	0	98	16.49	.08	.81	5.1	14.7 to 19.2
4	6	0	91	16.61	.09	.90	5.4	14.6 to 18.3
5	0	0	98	16.74	.08	.82	4.9	14.9 to 18.7
5	6	0	108	16.92	.09	.97	5.7	14.4 to 19.1
6	0	0	93	17.29	.10	1.01	5.8	15.2 to 20.3
7	0	0	102	17.80	.12	1.18	6.6	15.3 to 22.3
8	0	0	93	18.45	.13	1.22	6.6	15.5 to 22.0
9	0	0	91	19.26	.14	1.37	7.1	15.5 to 23.2
10	0	0	78	19.71	.17	1.48	7.5	15.8 to 23.6
11	0	0	72	20.35	.19	1.58	7.8	17.0 to 24.0
12	0	0	70	20.81	.17	1.45	6.9	17.8 to 25.2
13	0	0	83	21.63	.19	1.69	7.8	18.1 to 25.9
14	0	0	93	22.79	.18	1.71	7.5	18.3 to 27.3
15	0	0	106	24.03	.17	1.75	7.3	20.4 to 29.8
16	0	0	115	25.01	.15	1.60	6.4	20.5 ot 29.9
17	0	0	118	25.49	.15	1.60	6.3	21.0 to 30.2
18	0	0	82	25.83	.19	1.70	6.6	21.3 to 30.0

TABLE 5

Thigh girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white females, covering the age period from birth to eighteen years

MEAN AGE GROUPING			CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. (Per cent)	RANGE
Year	*Month*	*Day*						
0	0	2	50	16.50	.13	.92	5.6	14.5 to 18.7
0	3	0	42	21.65	.42	2.75	12.6	17.0 to 28.9
0	6	0	87	24.36	.28	2.62	11.2	18.7 to 31.0
0	9	0	95	25.24	.24	2.37	9.4	20.5 to 32.8
1	0	0	93	25.82	.27	2.59	10.0	20.2 to 31.9
1	3	0	77	26.29	.28	2.44	9.3	21.0 to 31.8
1	6	0	68	26.61	.25	2.06	7.8	23.0 to 31.0
1	9	0	56	27.03	.26	1.92	7.1	22.6 to 30.9
2	0	0	54	27.68	.26	1.94	7.0	23.5 to 31.6
2	3	0	44	27.97	.25	1.66	5.9	24.4 to 31.9
2	6	0	40	28.67	.31	1.99	6.9	23.9 to 34.0
2	9	0	39	29.09	.30	1.86	6.4	24.3 to 32.7
3	0	0	41	29.89	.31	2.00	6.7	26.0 to 34.5
3	6	0	53	31.33	.33	2.39	7.6	26.8 to 38.1
4	0	0	55	32.61	.32	2.41	7.4	28.4 to 37.6
4	6	0	60	32.85	.27	2.09	6.4	28.8 to 39.0
5	0	0	92	33.31	.23	2.18	6.5	28.7 to 39.0
5	6	0	87	33.99	.32	2.96	8.7	28.5 to 47.5
6	0	0	77	34.66	.32	2.83	8.1	30.2 to 45.9
7	0	0	82	36.41	.39	3.56	9.8	30.0 to 52.5
8	0	0	71	38.70	.49	4.16	10.7	31.0 to 53.5
9	0	0	86	40.15	.46	4.22	10.5	32.2 to 54.1
10	0	0	90	41.46	.41	3.86	9.3	35.0 to 52.2
11	0	0	85	43.85	.47	4.30	9.8	36.9 to 56.5
12	0	0	96	46.13	.46	4.50	9.7	38.5 to 58.0
13	0	0	104	48.03	.45	4.64	9.7	39.4 to 62.5
14	0	0	123	50.40	.48	5.34	10.6	49.4 to 69.5
15	0	0	133	51.42	.56	6.45	12.6	49.5 to 73.9
16	0	0	124	52.79	.50	5.58	10.6	43.0 to 76.3
17	0	0	96	53.22	.48	4.70	8.8	43.7 to 66.1
18	0	0	73	53.31	.54	4.58	8.6	44.0 to 66.5

TABLE 6

Thigh girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white males, covering the age period from birth to eighteen years

MEAN AGE GROUPING								
Year	*Month*	*Day*	CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. *(Per cent)*	RANGE
0	0	2	50	16.48	.22	1.55	9.4	13.1 to 19.0
0	3	0	61	22.33	.26	2.04	9.1	17.6 to 27.0
0	6	0	104	25.16	.24	2.44	9.7	19.6 to 30.9
0	9	0	129	25.87	.21	2.42	9.4	19.0 to 32.0
1	0	0	135	26.03	.20	2.35	9.0	20.9 to 32.0
1	3	0	123	26.22	.18	2.05	7.8	21.9 to 31.5
1	6	0	102	26.74	.22	2.21	8.2	22.7 to 33.3
1	9	0	95	27.09	.21	2.05	7.6	22.9 to 33.3
2	0	0	91	27.93	.23	2.18	7.8	23.0 to 34.2
2	3	0	91	28.26	.22	2.10	7.4	24.0 to 33.4
2	6	0	81	28.36	.23	2.07	7.3	23.5 to 33.8
2	9	0	85	29.03	.22	2.05	7.1	24.2 to 33.6
3	0	0	68	29.84	.21	1.75	5.9	26.0 to 33.3
3	6	0	91	30.77	.19	1.85	6.0	25.8 to 34.8
4	0	0	98	31.35	.19	1.93	6.1	26.5 to 36.6
4	6	0	91	31.88	.22	2.12	6.7	27.9 to 37.2
5	0	0	98	32.57	.23	2.32	7.1	27.9 to 38.8
5	6	0	108	33.09	.24	2.54	7.7	28.4 to 39.6
6	0	0	93	33.84	.29	2.83	8.4	28.0 to 43.9
7	0	0	102	35.46	.33	3.33	9.4	28.8 to 48.4
8	0	0	93	37.71	.37	3.59	9.5	31.0 to 49.7
9	0	0	91	39.48	.42	3.96	10.0	32.0 to 51.6
10	0	0	78	40.91	.45	3.96	9.7	33.3 to 55.0
11	0	0	72	42.37	.52	4.41	10.4	35.3 to 55.2
12	0	0	70	43.62	.51	4.25	9.7	35.1 to 56.7
13	0	0	83	45.57	.51	4.66	10.2	36.1 to 58.2
14	0	0	93	47.12	.44	4.21	8.9	38.3 to 62.0
15	0	0	106	49.39	.45	4.63	9.4	39.9 to 67.7
16	0	0	115	50.43	.38	4.10	8.1	41.5 to 66.2
17	0	0	118	51.88	.41	4.48	8.6	40.2 to 66.5
18	0	0	82	52.73	.52	4.73	9.0	41.2 to 70.4

TABLE 7

Leg girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white females, covering the age period from birth to eighteen years

MEAN AGE GROUPING								
Year	*Month*	*Day*	CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. *(Per cent)*	RANGE
0	0	2	50	10.78	.08	.58	6.0	8.5 to 10.9
0	3	0	42	13.99	.26	1.66	11.9	8.8 to 17.6
0	6	0	87	16.05	.14	1.31	8.4	13.0 to 20.0
0	9	0	95	16.70	.12	1.17	7.0	14.0 to 19.4
1	0	0	95	17.45	.14	1.39	7.9	13.8 to 21.0
1	3	0	78	18.03	.14	1.21	6.6	15.3 to 20.7
1	6	0	68	18.56	.15	1.24	6.7	15.0 to 21.5
1	9	0	57	18.87	.17	1.29	6.8	16.0 to 22.0
2	0	0	53	19.19	.15	1.12	5.8	16.8 to 22.2
2	3	0	45	19.41	.15	1.01	5.2	17.4 to 21.2
2	6	0	40	19.72	.18	1.14	5.8	17.8 to 22.2
2	9	0	39	20.25	.17	1.06	5.2	18.0 to 22.3
3	0	0	41	20.60	.18	1.12	5.4	18.5 to 23.5
3	6	0	53	21.25	.16	1.17	5.5	19.1 to 24.5
4	0	0	55	21.78	.15	1.09	5.0	19.4 to 24.8
4	6	0	60	21.97	.16	1.22	5.6	19.5 to 25.9
5	0	0	92	22.38	.14	1.33	5.9	19.2 to 26.0
5	6	0	88	22.91	.17	1.59	6.9	20.3 to 29.3
6	0	0	77	23.49	.19	1.68	7.1	20.5 to 30.6
7	0	0	82	24.37	.21	1.89	7.7	20.1 to 32.1
8	0	0	71	25.66	.25	2.12	8.3	21.9 to 33.0
9	0	0	84	26.59	.23	2.15	8.1	22.5 to 32.7
10	0	0	90	27.44	.23	2.22	8.0	22.6 to 33.6
11	0	0	85	28.66	.27	2.50	8.7	23.4 to 36.0
12	0	0	96	29.88	.25	2.49	8.3	23.5 to 34.5
13	0	0	104	31.03	.24	2.40	7.7	26.1 to 36.8
14	0	0	122	32.15	.26	2.92	9.1	21.7 to 42.2
15	0	0	133	32.77	.27	3.06	9.3	27.4 to 42.9
16	0	0	124	33.30	.24	2.69	8.1	28.8 to 43.7
17	0	0	96	33.38	.26	2.54	7.6	29.1 to 44.7
18	0	0	72	33.25	.28	2.38	7.1	28.5 to 42.6

TABLE 8

Leg girth (centimeters): mean, standard error of mean, standard deviation, coefficient of variation, and range for thirty-one distributions of Iowa City white males, covering the age period from birth to eighteen years

MEAN AGE GROUPING			CASES	MEAN	STANDARD ERROR OF MEAN	S. D.	C. OF V. (Per cent)	RANGE
Year	*Month*	*Day*						
0	0	2	50	11.03	.13	.89	8.1	9.0 to 12.6
0	3	0	61	14.73	.16	1.25	8.5	11.8 to 18.0
0	6	0	104	16.53	.12	1.18	7.2	13.7 to 19.4
0	9	0	129	17.25	.11	1.25	7.3	13.2 to 20.5
1	0	0	135	17.81	.10	1.22	6.9	15.1 to 20.6
1	3	0	123	18.24	.11	1.24	6.8	15.1 to 21.5
1	6	0	102	18.71	.12	1.20	6.4	16.3 to 21.5
1	9	0	95	19.01	.13	1.27	6.7	16.6 to 21.8
2	0	0	91	19.49	.14	1.35	6.9	16.9 to 22.8
2	3	0	91	19.89	.14	1.36	6.8	16.8 to 23.1
2	6	0	81	19.98	.12	1.10	5.5	18.1 to 22.5
2	9	0	85	20.27	.13	1.16	5.7	17.1 to 23.0
3	0	0	68	20.59	.14	1.16	5.6	18.2 to 23.0
3	6	0	91	21.20	.12	1.18	5.6	18.0 to 23.5
4	0	0	98	21.57	.11	1.12	5.2	19.1 to 24.5
4	6	0	91	21.92	.13	1.24	5.7	19.3 to 24.9
5	0	0	98	22.37	.12	1.21	5.4	19.6 to 25.5
5	6	0	108	22.62	.13	1.34	5.9	20.0 to 26.3
6	0	0	93	23.27	.16	1.56	6.7	20.1 to 28.0
7	0	0	102	24.29	.17	1.69	7.0	20.9 to 30.3
8	0	0	93	25.58	.18	1.77	6.9	22.5 to 30.5
9	0	0	91	26.82	.23	2.20	8.2	22.2 to 33.2
10	0	0	78	27.61	.26	2.26	8.2	23.3 to 33.8
11	0	0	72	28.39	.30	2.56	9.0	23.5 to 35.8
12	0	0	70	29.28	.29	2.43	8.3	24.4 to 36.7
13	0	0	83	30.71	.29	2.64	8.6	24.7 to 38.0
14	0	0	93	32.01	.26	2.49	7.8	26.6 to 37.3
15	0	0	106	33.43	.23	2.38	7.1	27.9 to 40.4
16	0	0	115	34.19	.20	2.21	6.2	29.1 to 41.0
17	0	0	118	34.63	.24	2.57	7.4	27.2 to 41.0
18	0	0	82	35.28	.29	2.67	7.6	27.4 to 42.2

TABLE 9

Percentage increases during thirty age intervals for each of four limb girths on Iowa City white females

AGE INTERVAL		ARM GIRTH	FOREARM GIRTH	THIGH GIRTH	LEG GIRTH
Year Month	*Year Month*				
Quarterly Percentage Increments					
0 0	to 0 3	19.7	17.8	31.2	29.7
0 3	to 0 6	12.4	13.9	12.5	14.8
0 6	to 0 9	2.9	2.9	3.6	4.0
0 9	to 1 0	3.9	2.8	2.3	4.5
1 0	to 1 3	1.6	1.5	1.8	3.4
1 3	to 1 6	1.2	1.1	1.2	2.9
1 6	to 1 9	.7	1.8	1.6	1.7
1 9	to 2 0	1.0	.2	2.4	1.7
2 0	to 2 3	.5	.8	1.1	1.1
2 3	to 2 6	2.5	1.5	2.5	1.6
2 6	to 2 9	.9	1.6	1.5	2.7
2 9	to 3 0	1.9	1.0	2.8	1.7
Semi-annual Percentage Increments					
3 0	to 3 6	3.5	3.4	4.8	3.2
3 6	to 4 0	2.4	2.1	4.1	2.5
4 0	to 4 6	.3	— .1	.7	.9
4 6	to 5 0	1.3	1.2	1.4	1.9
5 0	to 5 6	1.8	1.8	2.0	2.4
5 6	to 6 0	.9	.7	2.0	2.5
Annual Percentage Increments					
6 0	to 7 0	3.8	2.6	5.1	3.8
7 0	to 8 0	5.1	3.6	6.3	5.3
8 0	to 9 0	3.1	2.5	3.7	3.7
9 0	to 10 0	3.3	2.6	3.3	3.2
10 0	to 11 0	4.6	3.5	5.8	4.5
11 0	to 12 0	4.5	4.9	5.2	4.2
12 0	to 13 0	4.1	2.8	4.1	3.9
13 0	to 14 0	4.3	4.2	4.9	3.6
14 0	to 15 0	2.5	2.0	2.0	2.0
15 0	to 16 0	1.6	1.1	2.7	1.6
16 0	to 17 0	— .2	— .7	.8	.2
17 0	to 18 0	.7	.1	.2	— .4

TABLE 10

Percentage increases during thirty age intervals for each of four limb girths on Iowa City white males

AGE INTERVAL		ARM GIRTH	FOREARM GIRTH	THIGH GIRTH	LEG GIRTH
Year Month	*Year Month*				
Quarterly Percentage Increments					
0 0	to 0 3	23.9	23.1	35.5	33.5
0 3	to 0 6	9.4	10.1	12.7	12.2
0 6	to 0 9	4.8	4.0	2.8	4.4
0 9	to 1 0	2.3	1.9	.6	3.2
1 0	to 1 3	.2	.7	.7	2.5
1 3	to 1 6	1.3	.9	2.0	2.6
1 6	to 1 9	.8	1.1	1.3	1.6
1 9	to 2 0	2.0	1.5	3.1	2.5
2 0	to 2 3	1.4	1.2	1.2	2.1
2 3	to 2 6	— 1.1	— .6	.3	.4
2 6	to 2 9	1.3	1.9	2.4	1.5
2 9	to 3 0	2.0	1.7	2.8	1.6
Semi-annual Percentage Increments					
3 0	to 3 6	3.2	2.6	3.1	3.0
3 6	to 4 0	1.3	1.5	1.9	1.7
4 0	to 4 6	.9	.7	1.7	1.6
4 6	to 5 0	.2	.8	2.1	2.1
5 0	to 5 6	1.0	1.1	1.6	1.1
5 6	to 6 0	2.8	2.2	2.3	2.9
Annual Percentage Increments					
6 0	to 7 0	3.6	2.9	4.8	4.4
7 0	to 8 0	4.3	3.7	6.4	5.3
8 0	to 9 0	4.5	4.4	4.7	4.9
9 0	to 10 0	2.7	2.4	3.6	3.0
10 0	to 11 0	4.0	3.2	3.6	2.8
11 0	to 12 0	2.0	2.3	2.9	3.2
12 0	to 13 0	2.5	3.9	4.5	4.9
13 0	to 14 0	4.5	5.3	3.4	4.2
14 0	to 15 0	6.2	5.5	4.8	4.4
15 0	to 16 0	3.5	4.1	2.1	2.3
16 0	to 17 0	3.7	1.9	2.9	1.3
17 0	to 18 0	2.9	1.4	1.6	1.9

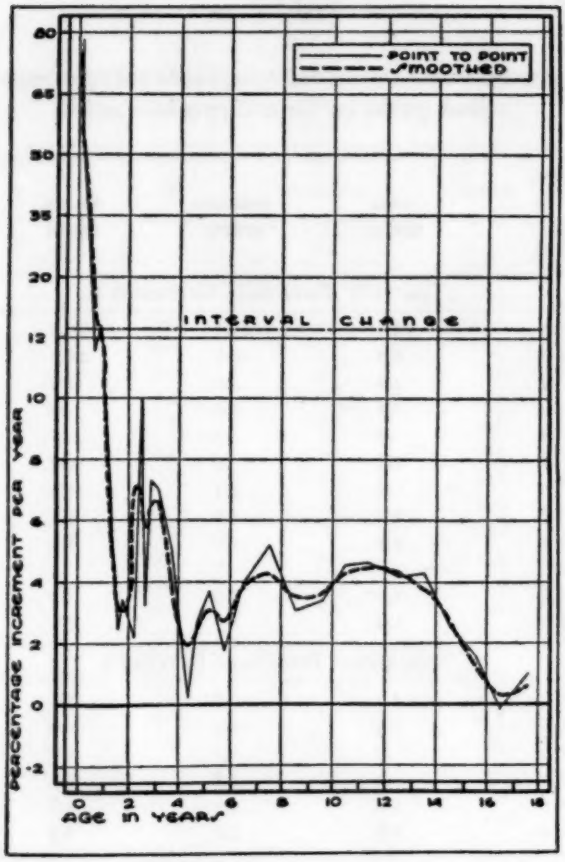

FIG. 5. ANNUAL RATE OF PERCENTAGE INCREASE IN ARM CIRCUMFERENCE FOR IOWA CITY FEMALES.

The point-to-point curve was derived from the values given in Table 9. The smoothed trend gives a semischematic representation of the relative acceleration-retardation rhythm for arm circumference of females.

coefficients are least for forearm (4.7 per cent), intermediate for leg and arm, and greatest for thigh (5.9 per cent). Maximum values are smallest for forearm (10.4 per cent for females, 8.4 per cent for males), intermediate for leg and thigh, and largest for girth of arm (13.3 per cent for females, 11.3 per cent for males).

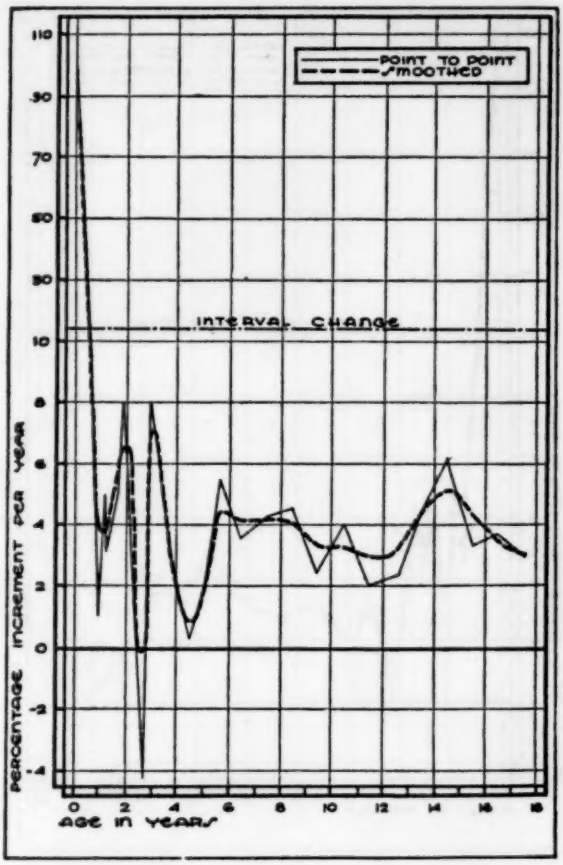

FIG. 6. RELATIVE VELOCITY OF GROWTH FOR GIRTH OF ARM IN IOWA CITY MALES.

The percentage increment figures for arm girth shown in Table 10 were used in constructing the point-to-point curve. The smooth trend minimizes the minor irregularities found for this dimension and emphasizes the major rate cycles.

Wide individual differences are found. Males at the upper end of the forearm and arm distributions at three months of age are approximately equal in these girths with males at the lower end of corresponding distributions at six years of age. Similarly, the females with the

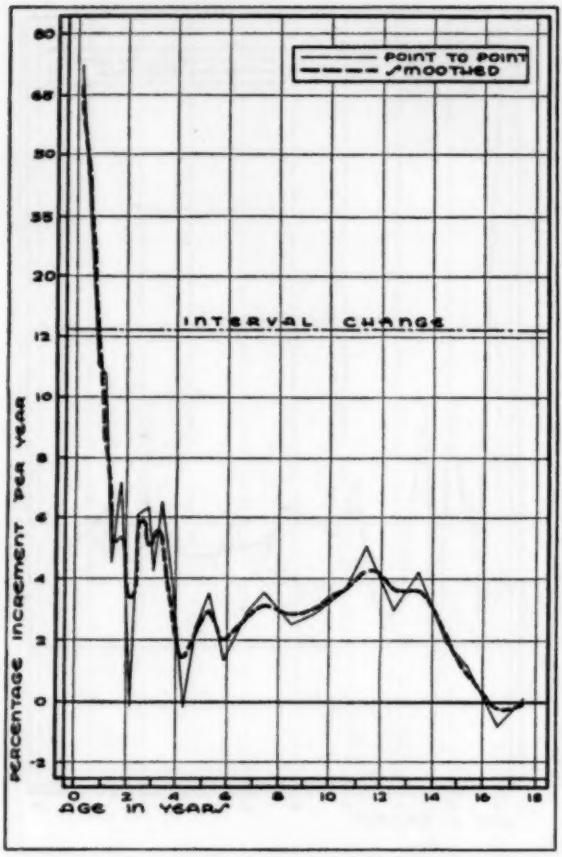

FIG. 7. ANNUAL PERCENTAGE RATE OF GROWTH IN GIRTH OF FOREARM FOR IOWA CITY FEMALES.

The point-to-point curve was based upon the increment values for forearm girth given in Table 9. The smoothed curve represents the major phases of forearm growth.

greatest arm girths at six years of age exceed the females with the smallest arm girths at eighteen years and the females with the smallest forearm girths at eighteen years are exceeded by the females with the largest forearm girths at six years of age. For females, the upper end of the thigh girth distribution at three months overlaps the lower end of the distribution for thigh girth at five years. For males, the upper

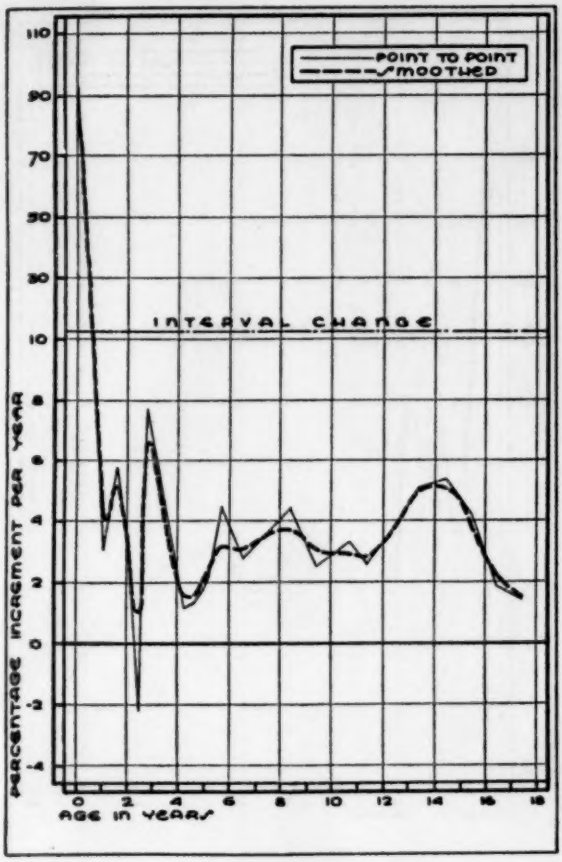

FIG. 8. MEAN INCREMENT TREND, IN PER CENT PER YEAR, FOR GIRTH OF FOREARM IN IOWA CITY MALES.

The point-to-point curve was derived from Table 10. The smoothed trend brings out the relative growth rhythm for this measurment.

end of the leg distribution at three months overlaps the lower end of the distribution for this girth at four years. Some males and females in our samplings have larger girths of both upper and lower limbs at six years than have some males and females in our eighteen-year samplings.

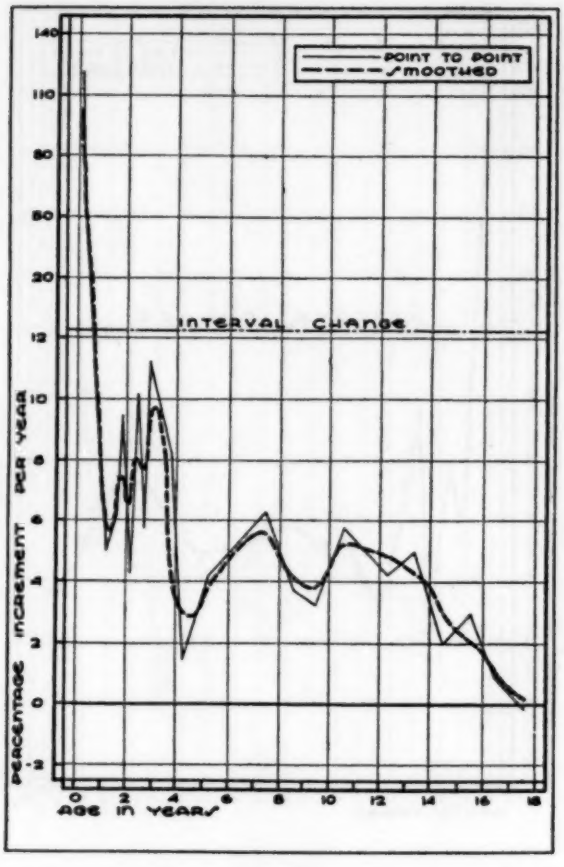

FIG. 9. ANNUAL RATE OF PERCENTAGE INCREASE IN THIGH CIRCUMFERENCE FOR IOWA CITY FEMALES.

The point-to-point curve was derived from the values given in Table 9. The smoothed trend gives a semischematic representation of the relative acceleration-retardation rhythm for thigh circumference of females.

Percentage increment

Percentage increment values, derived from the series of means given in Tables 1 to 8, are presented in Tables 9 and 10. These values cover the entire age period studied and were calculated by application of

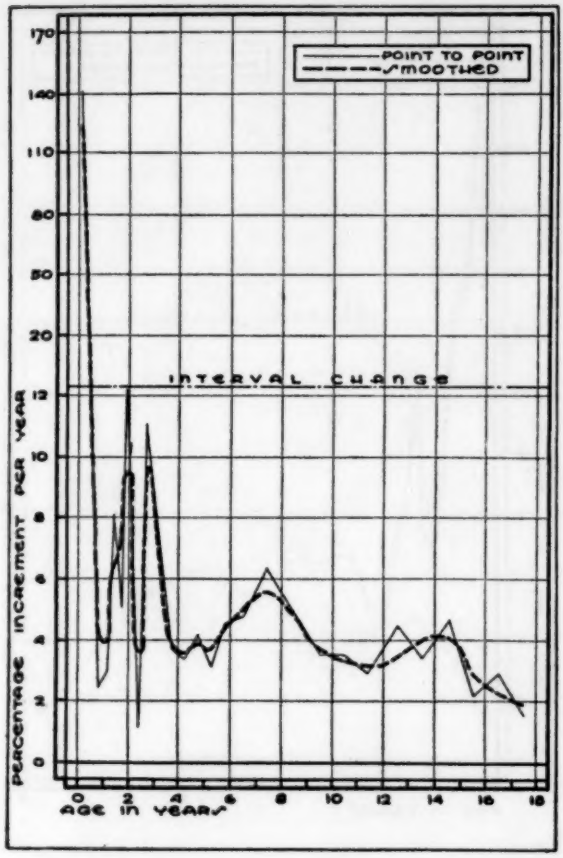

FIG. 10. RELATIVE VELOCITY OF GROWTH FOR GIRTH OF THIGH IN IOWA CITY MALES.

The percentage increment figures for thigh girth shown in Table 10 were used in constructing the point-to-point curve. The smooth trend minimizes the minor irregularities found for this dimension and emphasizes the major rate cycles.

Minot's arithmetic formula[3] to the successive means for each limb girth on each sex. Since the means are obtained from age groupings of vary-

[3] This formula required that the mean for a given limb girth at a given age be subtracted from the mean for the same girth at the next older age and that the difference be divided by the mean at the earlier age.

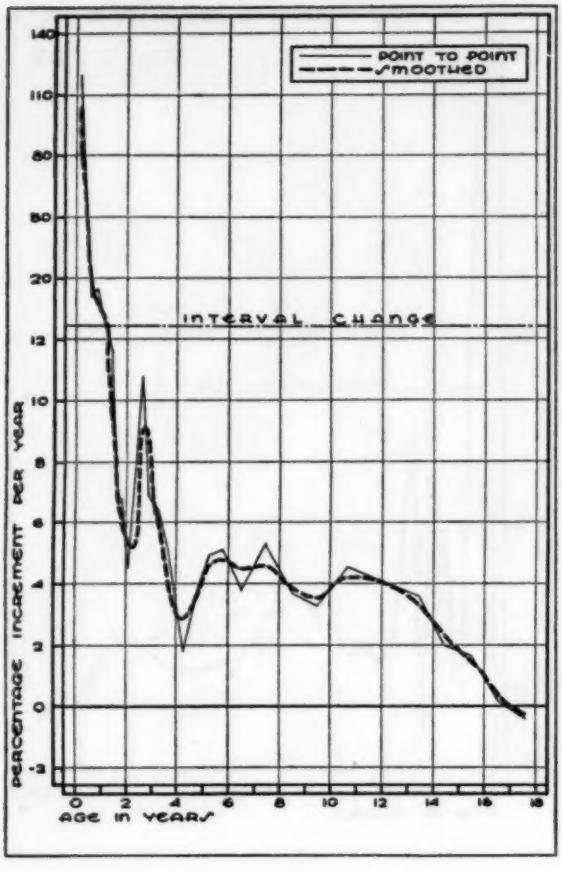

FIG. 11. ANNUAL PERCENTAGE RATE OF GROWTH IN GIRTH OF LEG FOR IOWA CITY FEMALES.

The point-to-point curve was based upon the increment values for leg girth given in Table 9. The smoothed curve represents the major phases of leg girth.

ing size, it follows that different portions of the series of percentage increases represent unlike units of time. From birth to three years of age the percentage gains are in quarterly terms, between three and six years of age in semiannual terms, and above six years in terms of percentage increment per year. To facilitate visualization of the entire percentage-rate trend from birth to eighteen years of age, the quarterly values were multiplied by four and the semiannual values by two.

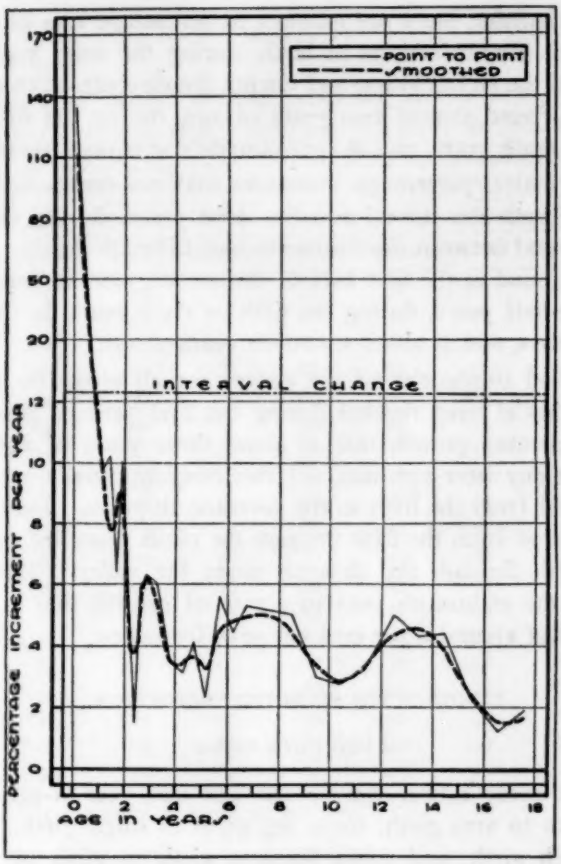

FIG. 12. MEAN INCREMENT TREND, IN PER CENT PER YEAR, FOR GIRTH OF LEG IN IOWA CITY MALES.
The point-to-point curve was derived from Table 10. The smoothed trend brings out the relative growth rhythm for this measurement.

Figures 5 to 12 show the resulting point-to-point trends in annual terms and also smoothed[4] trends based on the point-to-point values. Findings yielded by these graphs are as follows:

[4]A three-point, weighted method of smoothing was used. The formula for all but the extreme values was three times the figure to be smoothed plus the figure immediately above and the figure immediately below, this sum divided by five. The formula for the extreme values was three times the figure to be smoothed plus the figure immediately above or below, this sum divided by four.

1. For females, there are maxima in percentage rate of growth of the four limb circumferences at birth, during the third year, between the sixth and the eighth years, and during the eleventh or twelfth years. Minima are found around two years of age, during the fifth year, in the ninth or tenth years, and at approximately seventeen years of age.

2. For males, percentage increment maxima occur at birth, near the close of both the second and the third years, during the sixth to ninth years, and between the thirteenth and fifteenth years. Consistent minima are found in the first half of the second year, at approximately two and one-half years, during the fifth or sixth years, in the eleventh or twelfth years, and at about seventeen years of age.

3. Marked similarities of the curves for all girths on both sexes are (*a*) an initial steep descent during the first year of postnatal life, (*b*) an accelerated growth rate at about three years of age which is unequaled at any later age, and (*c*) two roughly convex arcs covering the age period from the fifth to the seventeenth years. The earlier arc spans the period from the fifth through the ninth years for females and from the fifth through the eleventh years for males. The later arc descends at the eighteenth year to a rate of growth that is negligible for females but around 2 per cent per year for males.

FINDINGS FOR SELECTED PROPORTIONS

Limb girth ratios

Table 11 gives ratios, specific for sex and year-of-age, of mean forearm girth to arm girth, mean leg girth to thigh girth, mean arm girth to thigh girth, and mean forearm girth to girth of leg. The findings which accrue from this table are:

1. During the age interval from birth to eighteen years, the ratio of mean forearm circumference to mean circumference of arm decreases more than 10 per cent for females while for males it fluctuates within a narrow zone of 3 per cent.

2. Mean leg circumference in percentage of mean thigh circumference, for females, increases from 65 at birth to 69 at two years and then gradually decreases to 62 at eighteen years. The male percentages are confined between 67 and 69 throughout the entire age span studied.

3. For females, there is a gradual decrease in arm girth — thigh girth ratio and in forearm girth — leg girth ratio covering the first eighteen postnatal years. At birth mean forearm girth is 92 per cent

TABLE 11

Limb girths: four ratios derived from the yearly means for circumference of forearm, arm, thigh, and leg given in tables 1 to 8*

MEAN AGE (Years)	FOREARM GIRTH / ARM GIRTH		LEG GIRTH / THIGH GIRTH		ARM GIRTH / THIGH GIRTH		FOREARM GIRTH / LEG GIRTH	
	Females	Males	Females	Males	Females	Males	Females	Males
Birth	103	102	65	67	58	60	92	92
1	101	101	68	68	54	55	80	82
2	101	101	69	69	52	54	76	78
3	101	102	69	69	51	52	75	77
4	100	101	67	69	50	52	75	76
5	100	102	67	69	49	51	74	75
6	100	101	68	69	49	51	72	74
7	99	101	67	68	48	50	71	73
8	98	100	66	68	48	49	70	72
9	97	100	66	68	47	49	69	72
10	96	100	66	67	47	48	69	71
11	95	99	65	67	47	49	68	72
12	95	99	65	67	47	48	68	71
13	94	101	65	67	46	47	68	70
14	94	101	64	68	46	48	68	71
15	94	101	64	68	46	48	68	72
16	93	101	63	68	46	49	68	73
17	93	99	63	67	45	49	67	74
18	92	99	62	67	46	50	68	73

* These ratios are given in terms of per cent.

of mean leg girth and mean girth of the arm is 58 per cent of mean girth of the thigh. The former figure is decreased by 24 and the latter figure by 12 at eighteen years of age.

4. For males, the ratios of arm girth to thigh girth and forearm girth to leg girth decrease from birth to thirteen years, and then gradually increase to eighteen years.[5] Forearm girth is 92 per cent of leg

[5] These trends are strikingly similar to the trends obtained by Wallis (15) for intermembral index of Iowa City children. Wallis found the mean arm length—leg length index to decrease from birth to eleven and twelve years of age for females and males, respectively, and to increase beyond these ages to eighteen years. It should be noted that the present study yields girth relationships for the two extremities which parallel the length relationships obtained by Wallis in the case of males only. Our figures for females show no rise during the teen years but, rather, register a continuing fall.

TABLE 12

Upper extremity: means for bi-condylar diameter of humerus, ratios of mean bi-condylar diameter of humerus to mean girth of arm, and ratios of mean bi-condylar diameter of humerus to mean girth of forearm for Iowa City white children at each year of age from birth to eighteen*

MEAN AGE (Years)	BREADTH OF ELBOW (Centimeters)		BREADTH OF ELBOW / GIRTH OF ARM (Per cent)		BREADTH OF ELBOW / GIRTH OF FOREARM (Per cent)	
	Females	Males	Females	Males	Females	Males
Birth	2.11	2.21	22	22	21	22
1	3.85	3.93	28	27	28	27
2	4.19	4.16	29	28	29	27
3	4.54	4.61	30	30	30	29
4	4.62	4.70	29	29	28	29
5	4.61	4.80	28	29	28	29
6	4.74	4.89	28	29	28	29
7	4.92	5.09	28	29	29	29
8	5.10	5.30	28	29	29	29
9	5.21	5.48	27	28	28	29
10	5.31	5.57	27	28	28	28
11	5.53	5.61	27	27	28	28
12	5.79	5.80	27	28	28	28
13	5.94	6.05	27	28	28	28
14	6.04	6.38	26	28	28	28
15	6.15	6.54	26	27	28	27
16	6.17	6.71	26	27	27	27
17	6.17	6.84	26	27	28	27
18	6.04	6.97	25	26	27	27

*These means for bi-condylar diameter of the left humerus were obtained from distributions for Iowa City children covering similar age periods and containing approximately the same number of observations as were the means for girth of arm and forearm (see Tables 1 to 4).

girth at birth, 70 per cent at thirteen years, and 73 per cent at eighteen years. Corresponding figures for arm girth in percentage of thigh girth are 60, 47, and 50, respectively.

Limb breadth — limb girth ratios

In order to secure some comparative findings for each extremity as to growth in circumference and in breadth, Tables 12 and 13 were pre-

TABLE 13

Lower extremity: means for bi-condylar diameter of femur, ratios of mean bi-condylar diameter of femur to mean girth of thigh, and ratios of mean bi-condylar diameter of femur to mean girth of leg for Iowa City white children at each year of age from birth to eighteen*

MEAN AGE (*Years*)	BREADTH OF KNEE (*Centimeters*)		BREADTH OF KNEE / GIRTH OF THIGH (*Per cent*)		BREADTH OF KNEE / GIRTH OF LEG (*Per cent*)	
	Females	Males	Females	Males	Females	Males
Birth	3.10	3.25	19	20	29	30
1	5.33	5.51	21	21	31	31
2	6.01	6.13	22	22	31	31
3	6.53	6.71	22	22	32	33
4	6.84	7.04	21	22	31	33
5	6.97	7.27	21	22	31	33
6	7.20	7.46	21	22	31	32
7	7.42	7.75	20	22	30	32
8	7.79	8.08	20	21	30	32
9	8.02	8.28	20	21	30	31
10	8.19	8.48	20	21	30	31
11	8.51	8.56	19	20	30	30
12	8.68	8.85	19	20	29	30
13	8.92	9.23	19	20	29	30
14	9.09	9.52	18	20	28	30
15	9.31	9.57	18	19	28	29
16	9.31	9.63	18	19	28	29
17	9.36	9.68	18	19	28	28
18	9.25	9.68	17	18	28	27

*These means for bi-condylar diameter of left femur were obtained from distributions for Iowa City children covering similar age periods and containing approximately the same number of observations as were the means for girth of thigh and leg (see Tables 5 and 8).

pared. The former table gives ratios of means for bi-condylar diameter of the humerus to means for circumference of arm and circumference of forearm. The latter table gives ratios of means for bi-condylar diameter of the femur to means for thigh circumference and leg circumference respectively. The primary findings revealed by these tables are:

TABLE 14

Means for stature, ratios of mean arm circumference to mean stature, and ratios of mean thigh circumference to mean stature for Iowa City white children at each year of age from birth to eighteen years*

MEAN AGE (*Years*)	STATURE MEANS (*Centimeters*)		ARM GIRTH / STATURE (*Per cent*)		THIGH GIRTH / STATURE (*Per cent*)	
	Females	Males	Females	Males	Females	Males
Birth	49.20	50.20	20	20	34	33
1	74.44	76.51	19	19	35	34
2	86.99	88.53	17	17	32	32
3	95.62	96.26	16	16	31	31
4	102.53	103.32	16	16	32	30
5	108.98	109.94	15	15	31	30
6	115.07	115.95	15	15	30	29
7	120.99	121.91	15	15	30	29
8	126.78	128.13	15	14	31	29
9	132.59	133.71	14	14	30	30
10	137.70	138.94	14	14	30	29
11	143.67	143.20	14	14	31	30
12	150.33	147.81	14	14	31	30
13	156.01	153.31	14	14	31	30
14	159.50	159.39	15	14	32	30
15	160.78	165.15	15	15	32	30
16	161.40	169.73	15	15	33	30
17	161.45	173.51	15	15	33	30
18	161.02	174.15	15	15	33	30

*These means are taken from studies on Iowa City Males by Meredith (9) and Iowa City females by Boynton (3). The distributions from which the means were derived contained a greater number of observations throughout than did the limb girth distributions.

1. Breadth of elbow for both sexes ranges between 21 and 30 per cent of girth of arm and girth of forearm during the age period from birth to eighteen years. Within the same age interval the breadth of knee has a mean size varying from 17 to 22 per cent of thigh girth and 27 to 33 per cent of leg girth.

2. The ratios for the upper extremity show no consistent sex differences in elbow breadth/forearm girth. From the beginning of the seventh year through the eighteenth year, females have a slightly larger

arm girth in relation to their elbow breadth than do males. For the lower extremity, females have somewhat larger thigh and leg circumferences in relation to knee breadth throughout the age span from four to eighteen years.

3. In general, the ratios for the upper and lower extremities increase from birth to three years of age and thereafter gradually decrease. It is thus found that the two limb girths of each extremity are largest in respect to a limb breadth for the same extremity at approximately the age when the limb girths are increasing at a faster rate than at any other time between two and eighteen years of age.

Limb girth — stature ratios

To compare growth in circumference of the upper and lower extremities to growth in stature, Table 14 was compiled. This table expresses means for arm girth and thigh girth in percentage of means for stature. Girth of forearm and girth of leg means were also calculated as percentages of stature means, but these figures are not included in the table since they showed no pertinent findings not revealed in the percentage series for girth of arm. Findings for the four limb girths in percentage of stature are as follows:

1. Girth of thigh ranges between 29 and 35 per cent of stature for both sexes, while girth of leg varies from 20 to 23 per cent and girths of arm and forearm between 14 and 20 per cent.

2. The four girths show a decrease in percentage of stature for each sex from birth to the eighth year and a period of relative constancy between the ninth and the fourteenth years. A final interval of slight increase is found from fifteen through eighteen years for girths of arm, forearm, and leg.

3. Over the entire age period studied females tend to show a larger thigh circumference in relation to stature than do males. This sex difference is particularly marked from fourteen to eighteen years of age. At eighteen years the male thigh circumference is 30 per cent of stature while the female circumference is 33 per cent.

SUMMARY

This study describes the growth of Iowa City white children with respect to circumference of arm, forearm, thigh, and leg during the period from birth to eighteen years.

The data consist of 2,373 measurement values for each girth on 771 females and 2,897 parallel values on 1,013 males accumulated between 1930 and 1935. The sample represents a population predominantly composed of the professional and managerial classes and is almost entirely of North European ancestry.

Curves of central tendency show that the forearm circumference of females is less than that for males throughout the entire age interval studied, while the thigh circumference of females is greater than that of males at all ages from two to eighteen years.

In general, absolute variability is least for forearm, intermediate for arm and leg, and greatest for thigh, whereas relative variability is least for forearm, intermediate for leg, and greatest for thigh and arm.

Individual differences are marked. Some males and females in the samplings at six years of age have larger girths of both upper and lower limbs than have some males and females at eighteen years.

Annual percentage increment curves for all girths on both sexes are characterized by an initial rapid descent during the first year following birth and a second maximum at about three years of age which is not exceeded at any later age. From the fifth year on, the curves take the form of two roughly concave arcs. The maximum of the second arc occurs about two years earlier for females (eleven to twelve years) than for males (thirteen to fifteen years). At eighteen years of age the rate of growth is found to be negligible for females and to fluctuate around 2 per cent for males.

Numerous findings are reported for proportional relations between the limb girths studied, and for limb girth growth in comparison to growth of selected limb breadths and of stature.

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THE QUANTITY OF CREATINE AND CREATININE EXCRETED IN NORMAL HUMAN PREGNANCY[1]

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SINCE Folin's first work on the quantitative determination of creatine and creatinine, our knowledge of these metabolites has been broadened by numerous studies. The important reviews of the subject are fully cited by Beard and Boggess (2). Much has been written and many experiments have been performed which were, or appeared to be, so contrived that a definite relationship could be shown to exist between a given variable and the metabolism of these substances; but as yet no extensive descriptive account of the quantities in which these substances are excreted in normal human pregnancy is available.

The early work of Murlin (6) consisted of daily urine analyses of 3 subjects during the last month of pregnancy and early puerperium. A limited number of figures are available in the work of Coons (4).

From the available data it is difficult to state whether the excretion of creatinine and creatine varies with time in pregnancy, or how much variation there is from one day to another. Whether any change in the excretion of one of these metabolites can be explained by a compensatory change in the other also remains unknown. Hormones (9) (10) (11) influence the excretion and the quantities in which creatine and creatinine appear in the urine could conceivably reflect the activity of the gonads or anterior pituitary.

With the view of establishing our information on a more precise quantitative basis, a considerable number of analyses were done at varying times and intervals during pregnancy, and the results treated statistically. The work consisted in part of a quantitative determination

[1] This work was done at the Samuel S. Fels Research Institute for Study in Prenatal and Postnatal Environment, under the supervision of Dr. L. W. Sontag, Director.

of urine creatine and creatinine at 28-day intervals, and in part of consecutive daily determinations. In order to take into account the influence of protein in the diet (cf. Beard and Boggess, 2) food nitrogen analyses were made by the Kjeldahl method. Except when daily analyses were made the subjects ate a uniform diet for 3 successive days and a 24-hour urine sample was obtained on the third day.[2] The diet of subject XIV was rigorously controlled. For 3 consecutive days she was repeatedly (7 times) given the same diet, quantitatively and qualitatively at 2-week intervals. In her case urine analyses were made on each of the 3 days instead of the last day only, and in addition, she was on a self-chosen and varied diet for 21 consecutive days during which time her food was also analyzed. Creatinine was determined by Folin's micro-method, and creatine was converted to creatinine by autoclaving.

TABLE 1

Variation of creatine and creatinine excretion with time in pregnancy

SUBJECT	NUMBER OF ANALYSES*	TIME & CREATININE EXCRETION**	TIME & CREATINE EXCRETION
XIII	26	$-.439 \pm .11$	$-.229 \pm .12$
XIV	47	$+.113 \pm .10$	$+.123 \pm .10$
III, VI, X.....	22	$+.376 \pm .12$	$+.168 \pm .15$

* The analyses for XIII were on specimens obtained within 48 days before delivery, and those for XIV within 119 days. All other analyses were done at 28 day intervals.

** Computed by the following formula:

$$r = \frac{\Sigma \overline{XY}}{\sqrt{\Sigma \overline{X}^2}\sqrt{\Sigma \overline{Y}^2}}; \text{ Probable error } = \frac{0.6745(1-r^2)}{\sqrt{n}}$$

From Table 1 it can be seen that during the observation period—as early as 238, 197 and 161 days before delivery—there was no change in the excretion of either creatine or creatinine which can be related to a given time in pregnancy. Only subject XIII showed a tendency to

[2] A more detailed account of the management of some of our subjects is given by Pyle and Huff (8).

excrete greater amounts of creatinine (negative correlation) toward the end of pregnancy. It is the view of the authors, which has support in statistical figures, that this tendency can be explained by the marked increase in body weight during the observation period (time and body weight, $r = -.96$; time, body weight, and creatinine, $R = +.44$).

The extent of the daily variability in excretion is given quantitative expression in Table 2. Without exception, the daily creatine excretion was more variable than the creatinine excretion. It is undoubtedly associated with a less stable metabolic mechanism than creatinine. The variation in creatinine excretion is comparable to that found for non-pregnant individuals (7). When subject XIV ate a uniform diet her

TABLE 2

Summary of data on daily nitrogen intake and daily creatine and creatinine excretion during pregnancy

SUBJECT	NUMBER OF DAYS	AVERAGE NITROGEN INTAKE (gms.)	CREATININE EXCRETED (gms.)	CREATINE EXCRETED (gms.)	COEFFICIENT OF VARIATION CREATININE	COEFFICIENT OF VARIATION CREATINE	CREATININE TO CREATINE RATIO	CREATININE COEFFICIENT	PREDICTED URINE CREATININE ***
III$_b$	7*	11.79±0.35	1.453±0.03	0.563±0.04	6.9	31.8	2.58	8.2	1.43
VI	7*	10.36±0.62	0.837±0.001	0.939±0.02	0.7	33.5	0.89	5.6	1.23
X	8*	12.96±0.59	1.570±0.03	0.491±0.06	7.0	51.8	3.99	8.0	1.60
IX	7	12.87±0.09	1.445±0.06	0.393±0.05	17.1	52.2	3.68	6.8	1.51
XV	7	.....	1.190±0.05	.....	16.6	....	...	6.3	1.53
VIII	5	9.53	1.273±0.04	0.421±0.07	11.9	52.3	3.02	7.1	1.48
VII	3*	13.37	1.247	0.800	....	....	1.57	7.2	1.41
XIII	26	.....	0.895±0.04	0.375±0.09	33.6	184.7	2.39	5.7	1.29
XIV	21	11.35±0.21	0.978±0.04	0.361±0.07	29.5	130.4	2.71	7.0**	1.16
XIV****	21	13.51±0.05	0.964±0.06	0.436±0.08	40.3	120.2	2.21	...	....
XI	3	12.45	1.212	0.600	....	....	2.02	8.0	1.27
				Average		2.51±0.21		7.0	

* Analyses made at 28-day intervals.
** Average of all analyses made.
*** Cr. $N = 12.7M^{0.\overline{000}}$.
**** On prescribed diet.

daily creatine excretion did not decrease in variability and the daily creatinine excretion continued to be second in variability to only 1 other subject. Thus no effect of diet on the excretion of these metabolites was revealed here. In line with this special case, no significant correlation was found between nitrogen intake and creatine excretion or between nitrogen intake and creatinine excretion (Table 3).

A relationship of possible importance is the relative daily quantities (Table 2) in which these substances were excreted. In the 9 cases the average daily creatinine to creatine ratio was 2.51 ± 0.21. In view of the probable error, this is not a good prediction figure. Perhaps this ratio can be of practical value when its physiological significance is more fully understood. It is noteworthy that subject VI, with the low figure of 0.89 for this ratio, had an unusually low variability in daily creatinine excretion.

Whether the absolute quantity of creatinine excreted during pregnancy is usually different from that in the non-gravid condition cannot be shown adequately from our data. The average creatinine coefficient[3] in our group is higher than has usually been found for non-pregnant women. Of the 10 averages cited by McLaughlin and Blunt (5) only 3 are higher than the average of our group. On the other hand, in all cases except 1, less creatinine was excreted than is predicted (see Table 2) by the equation derived from data collected on both male and female animals (3). In 3 cases it was possible to obtain more direct evidence by analyzing the urine in the post lactation period. These results compare with the averages in Table 2 as follows:

		Creatinine
Subject III	1.371[4]	1.453±0.03
Subject VI	0.838	0.837±0.001
Subject X	1.371	1.570±0.03

Two of these may be considered indecisive, but suggest a tendency toward a greater excretion during pregnancy. The post lactation urine

[3] The creatinine excretion for mature animals of different species, varies directly with the 0.893 power of body weight (3) and hence an error is incurred in this coefficient. It is here retained for the purpose of facilitating comparison. The prediction equation also involves an error, of unknown magnitude, because it (0.893) applies only to mature animals, and the metabolism of pregnancy is not comparable to that of maturity.

[4] The figures in this column represent an average of two 24-hour post lactation excretions. The other figures are reproduced from Table 2.

of Subject VI contained 0.610 gms. of creatine, which explains, in part, her low creatinine to creatine ratio during pregnancy.

The relationship between creatine and creatinine in pregnancy is apparently not simply explainable on the basis of an increased excretion of the one at the expense of the other. Only one significant correlation was found between the excretion of the two when the subjects were considered individually (Table 3).

SUMMARY

The daily creatine and creatinine excretion of nine normal human subjects was studied at various times during pregnancy. The variability in the excretion of creatinine was always less than that of the excretion of creatine, and the quantity of creatine or creatinine excreted does not appear to change appreciably with time in pregnancy. The average urinary creatinine to creatine ratio was 2.51 ± 0.21. One subject excreted more creatine than creatinine during pregnancy, and after delivery her daily creatine excretion was high. No correlation was found between nitrogen intake and the elimination of either creatine or creatinine.

TABLE 3

Correlations showing the relationships between protein intake, creatine excretion and creatinine excretion

SUBJECT	NITROGEN INTAKE AND CREATINE EXCRETION r	NITROGEN INTAKE AND CREATININE EXCRETION r	CREATINE AND CREATININE EXCRETION r
VIII	.....	.....	−.087±0.29
VI	−.413±0.21	−.108±0.25	+.011±0.25
III_b	−.474±0.19	−.015±0.25	+.015±0.25
IX	+.386±0.21	−.126±0.25	−.651±0.15
XIV*	.....	.....	−.237±0.14
XIV	−.128±0.14	+.212±0.14	−.231±0.14
XIII	.....	.....	−.210±0.12
X	−.501±0.18	−.034±0.24	+.187±0.23

* On same diet repeatedly.

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ON THE MOMENT PRODUCT-SUMS OF CURTATE FREQUENCY DISTRIBUTIONS[1]

BY RAYMOND PEARL

I

IN BIOMETRIC work it is sometimes desired to know the values of the standard constants—mean, standard deviation, etc.—not only for the entire frequency distribution as observed, but also for this distribution less one or more of the end classes at one end or the other. The purpose of this paper is to present a time-saving short cut in the computation of the constants for such curtate distributions.

II

Let $f_1, f_2, f_3 \ldots\ldots f_s$ be the elemental frequencies, so that the whole size of the sample $N = f_1 + f_2 + \ldots\ldots + f_s = S(Z)$ in the usual terminology,[2] in which, and in all that follows below, S denotes summation.

Consider an original frequency distribution of the following sort for which the raw moments about the center of the class at the lower range end are desired, where x denotes deviations in class units from the origin, and Z denotes frequencies in general.

III

Consider next the curtate distribution derived from the original distribution by dropping the first class of frequency f_1. We shall then have the situation shown in Table 2, where the subscript $c1$ indicates curtation by deletion of one frequency class.

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[1] From the Department of Biology of the School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland.

[2] Cf. Pearl, R. Introduction to Medical Biometry and Statistics. Second Edit. 1930, p. 338 ff.

TABLE 1

Z	x	Zx	Zx^2	Zx^3	Zx^4
f_1	0	0	0	0	0
f_2	1	$1f_2$	$1f_2$	$1f_2$	$1f_2$
f_3	2	$2f_3$	$4f_3$	$8f_3$	$16f_3$
f_4	3	$3f_4$	$9f_4$	$27f_4$	$81f_4$
f_5	4	$4f_5$	$16f_5$	$64f_5$	$256f_5$
..	..	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
f_n	$(n-1)$	$(n-1)f_n$	$(n-1)^2f_n$	$(n-1)^3f_n$	$(n-1)^4f_n$

The raw moments about the arbitrarily chosen origin will then be

$$\nu_1 = \frac{S(Zx)}{S(Z)}$$

$$\nu_2 = \frac{S(Zx^2)}{S(Z)}$$

etc.

TABLE 2

Z_{c1}	x_{c1}	$Z_{c1}x_{c1}$	$Z_{c1}x^2_{c1}$	$Z_{c1}x^3_{c1}$	$Z_{c1}x^4_{c1}$
f_1	-1	$(-1)f_1$	$(+1)f_1$	$(-1)f_1$	$(+1)f_1$
f_2	0	0	0	0	0
f_3	1	$1f_3$	$1f_3$	$1f_3$	$1f_3$
f_4	2	$2f_4$	$4f_4$	$8f_4$	$16f_4$
f_5	3	$3f_5$	$9f_5$	$27f_5$	$81f_5$
..	..	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
f_n	$(n-2)$	$(n-2)f_n$	$(n-2)^2f_n$	$(n-3)^2f_n$	$(n-2)^4f_n$

The problem now is to determine the sums of the columns of this distribution made curtate by dropping the first frequency class (that part of the table above the horizontal rule).

We have, plainly

$$x_{c_1} = x - 1, \qquad (i)$$

and

$$S(Z_{c_1}) = [S(Z)] - [f_1]. \qquad (ii)$$

Now, remembering that all xs *below* the horizontal rule in Table 2 are, in the nature of the case, positive, and all xs above the horizontal rule are negative, we have:

$$S(Z)x_{c_1} = S(Zx) - S(Z),$$

from which must be subtracted

$$f_1(x-1) = f_1(0-1) = -f_1.$$

This gives

$$S(Z_{c_1}x_{c_1}) = S(Zx) - S(Z) + f_1, \qquad (iii)$$

which expresses the first moment product-sum of the curtate distribution in terms of the sums of the columns of the original distribution and the elemental frequency dropped in the curtation.

Proceeding in the same manner to find the second moment we have, since

$$x_{c_1}^2 = (x-1)^2 = x^2 - 2x + 1,$$
$$S(Z)x_{c_1}^2 = S(Zx^2) - 2S(Zx) + S(Z),$$

from which as before must be subtracted

$$f_1\ (x^2 - 2x + 1) = 0 - 0 + f_1,$$

giving as the end result,

$$S(Z_{c_1}x_{c_1}^2) = S(Zx^2) - 2S(Zx) + S(Z) - f_1. \qquad (iv)$$

For the third moment we have, since

$$x_{c_1}^3 = x^3 - 3x^2 + 3x - 1,$$
$$S(Z)x_{c_1}^3 = S(Zx^3) - 3S(Zx^2) + 3S(Zx) - S(Z),$$

from which, as before, we subtract

$$f_1(x^3 - 3x^2 + 3x - 1) = 0 - 0 + 0 - f_1,$$

which leads to

$$S(Z_{c_1}x_{c_1}^3) = S(Zx^3) - 3S(Zx^2) + 3S(Zx) - S(Z) + f_1. \qquad (v)$$

Finally for the fourth moment product-sum we have. by the same procedure

$$S(Z_{c_1}x_{c_1}^4) = S(Zx^4) - 4S(Zx^3) + 6S(Zx^2) - 4S(Zx) + S(Z) - f_1. \qquad (vi)$$

IV

A simple extension of the same process will give the moment product-sums, in terms of those for the original distribution, for a distribution made curtate by dropping any number of consecutive frequency classes from the original distribution.

Consider as an illustration curtation by dropping the first two classes.

TABLE 3

Z_{c_2}	x_{c_2}	$Z_{c_2}x_{c_2}$	$Z_{c_2}x_{c_2}^2$	$Z_{c_2}x_{c_2}^3$	$Z_{c_2}x_{c_2}^4$
f_1	-2	$(-2)f_1$	$(+4)f_1$	$(-8)f_1$	$(+16)f_1$
f_2	-1	$(-1)f_2$	$(+1)f_2$	$(-1)f_2$	$(+1)f_2$
f_3	0	0	0	0	0
f_4	1	$1f_4$	$1f_4$	$1f_4$	$1f_4$
f_5	2	$2f_5$	$4f_5$	$8f_5$	$16f_5$
..	..	..	..	..	..
..	..	..	..	..	..
..	..	..	..	..	..
f_n	$(n-3)$	$(n-3)f_n$	$(n-3)^2f_n$	$(n-3)^3f_n$	$(n-3)^4f_n$

Here

$$x_{c_2} = x - 2, \tag{vii}$$

and

$$S(Z_{c_2}) = [S(Z)] - [f_1] - [f_2]. \tag{viii}$$

Proceeding as before we have

$$S(Z)x_{c_2} = S(Zx) - 2S(Z),$$

from which must be subtracted first

$$f_1(x-2) = f_1(0-2) = -2f_1,$$

and then

$$f_2(x-2) = f_2(1-2) = -f_2.$$

This leads to

$$S(Z_{c_2}x_{c_2}) = S(Zx) - 2S(Z) + 2f_1 + f_2. \tag{ix}$$

Squaring and multiplying as before leads, for the second moment product sum, to

$$S(Z)x_{c_2}^2 = S(Zx^2) - 4S(Zx) + 4S(Z),$$

from which are to be successively subtracted

$$f_1(x-2)^2 = f_1(0-0+4) = 4f_1,$$

and

$$f_2(x-2)^2 = f_2(1-4+4) = f_2.$$

Whence

$$S(Z_{c_2}x_{c_2}^2) = S(Zx^2) - 4S(Zx) + 4S(Z) - 4f_1 - f_2. \quad (x)$$

By parity of procedure we may write down directly

$$S(Z_{c_2}x_{c_2}^3) = S(Zx^3) - 6S(Zx^2) + 12S(Zx) - 8S(Z) + 8f_1 + f_2, \quad (xi)$$

and

$$S(Z_{c_2}x_{c_2}^4) = S(Zx^4) - 8S(Zx^3) + 24S(Zx^2) - 32S(Zx) + 16S(Z) - 16f_1 - f_2. \quad (xii)$$

Since the same reasoning can be extended to any degree of curtation produced by dropping off frequency classes (provided the classes dropped are consecutive starting from either range end) the problem stated at the beginning appears to be solved. The moment product sums for any frequency distribution made curtate in the manner specified can be expressed in terms of (a) the moment product sums of the *original distribution* before curtation, and (b) the elemental *frequencies dropped* in curtation.

V

It is also possible, in the case of the simplest curtation (dropping a single terminal frequency class), to express the product-sums after curtation in terms of (a) the moment product sums of the *original* distribution, and (b) the lower order product sums of the *curtate* distribution. Thus, since $S(Z_{c_1}) = S(Z) - f_1$ equation (*iii*) may be written

$$S(Z_{c_1}x_{c_1}) = S(Zx) - S(Z_{c_1}). \quad (xiii)$$

Similarly equation (*iv*) is the same as

$$S(Z_{c_1}x_{c_1}^2) = S(Zx^2) - S(Zx) - S(Z_{c_1}x_{c_1}). \quad (xiv)$$

In the same way we may write:

$$S(Z_{c_1}x_{c_1}^3) = S(Zx^3) - S(Zx^2) - 2S(Z_{c_1}x_{c_1}^2) - S(Z_{c_1}x_{c_1}) \quad (xv)$$

$$S(Z_{c_1}x_{c_1}^4) = S(Zx^4) - S(Zx^3) - 3S(Z_{c_1}x_{c_1}^3) - 3S(Z_{c_1}x_{c_1}^2) - S(Z_{c_1}x_{c_1}) \quad (xvi)$$

VI

Let us now check the results by the simple numerical example given in Table 4, which gives the product sums by direct arithmetic calculation.

TABLE 4

Original distribution

Z	x	Zx	Zx^2	Zx^3	Zx^4
2 (=f_1)	0	0	0	0	0
4 (=f_2)	1	4	4	4	4
8	2	16	32	64	128
4	3	12	36	108	324
2 (=f_4)	4	8	32	128	512
20	..	40	104	304	968

Curtate (c1) distribution

Z_{c1}	x_{c1}	$Z_{c1}x_{c1}$	$Z_{c1}x^2_{c1}$	$Z_{c1}x^3_{c1}$	$Z_{c1}x^4_{c1}$
..	..	..	..	..	..
4	0	0	0	0	0
8	1	8	8	8	8
4	2	8	16	32	64
2	3	6	18	54	162
18	..	22	42	94	234

Curtate (c2) distribution

Z_{c2}	x_{c2}	$Z_{c2}x_{c2}$	$Z_{c2}x^2_{c2}$	$Z_{c2}x^3_{c2}$	$Z_{c2}x^4_{c2}$
..	..	..	..	..	..
..	..	..	..	..	..
8	0	0	0	0	0
4	1	4	4	4	4
2	2	4	8	16	32
14	..	8	12	20	36

Now substituting *sums from the original distribution* we have:

From (*ii*), $S(Z_{c1}) = 20 - 2 = 18$.

From (*iii*), $S(Z_{c1}x_{c1}) = 40 - 20 + 2 = 22$; or from (*xiii*) $S(Z_{c1}x_{c1}) = 40 - 18 = 22$.

From (*iv*), $S(Z_{c1}x_{c1}^2) = 140 - 80 + 20 - 2 = 42$; or from (*xiv*) $S(Z_{c1}x_{c1}^2) = 104 - 40 - 22 = 42$.

From (*v*), $S(Z_{c1}x_{c1}^3) = 304 - 312 + 120 - 20 + 2 = 94$; or from (*xv*) $S(Z_{c1}x_{c1}^3) = 304 - 104 - 84 - 22 = 94$.

From (*vi*), $S(Z_{c_1}x_{c_1}^4) = 968 - 1216 + 624 - 160 + 20 - 2 = 234$;
or from (*xvi*) $S(Z_{c_1}x_{c_1}^4) = 968 - 304 - 282 - 126 - 22 = 234$.
From (*viii*), $S(Z_{c_2}) = 20 - 2 - 4 = 14$.
From (*ix*), $S(Z_{c_2}x_{c_2}) = 40 - 40 + 4 + 4 = 8$.
From (*x*), $S(Z_{c_2}x_{c_2}^2) = 104 - 160 + 80 - 8 - 4 = 12$.
From (*xi*), $S(Z_{c_2}x_{c_2}^3) = 304 - 624 + 480 - 160 + 16 + 4 = 20$.
From (*xii*), $S(Z_{c_2}x_{c_2}^4) = 968 - 2432 + 2496 - 1280 + 320 - 32 - 4 = 36$.

Thus it has been demonstrated that a biometric worker who has calculated the moment product-sums of a long frequency distribution, and who then wishes to get the corresponding moment product-sums for the same distribution made curtate to any desired degree, may save computational labor by the use of the equations set forth in this paper, or of similar equations for further degrees of curtation that he may derive by the further extension of the method here used.

NOTES

NOTE ON A NEW SLIDING CALIPERS FOR CRANIAL MEASUREMENTS, INCLUDING INTERNAL DIAMETERS

THE calipers figured and described in this note are properly to be regarded as a modification of the craniometer designed many years ago by Flower and bearing his name. They embody such improvements as we think will result in obtaining certain metrical data on the skull with a precision greater than can be secured by means of the majority of instruments now in common use. Their most original feature is a device enabling the craniometrician to measure readily internal diameters, that is to say, those of apertures, foramina and fossae. It has not hitherto been possible to accomplish this satisfactorily without resort to an engineers' gauge of the "Columbus" pattern or to ordinary geometrical dividers, the reading in the case of the latter being ascertained by applying the points to a boxwood or similar scale after each measurement. For example, the foraminal breadth, which may be regarded as the greatest visible diameter of the foramen magnum perpendicular to the axis of its length, is usually taken with sliding calipers that have tips singularly ill-adapted for the purpose in view. There is some room for error here, and though this may be slight, no reason exists why it should not as far as possible be eliminated. Such elimination can be effected by employing an instrument that practically of itself furnishes the maximum breadth of the foramen. With the present calipers this is easily achieved by placing the stationary short arm against one margin and then gently shifting the sliding socket along the bar until the sharp edge of the movable short arm is in contact with the other. A vernier on both sides of the socket allows the diameter thus obtained to be read to .1 mm.[1] The calibrated length of the bar is the regular 250 mm., that

[1] Lest such a degree of accuracy should seem unduly meticulous, we do not pretend that repeated measurements of any character to a tenth of a millimeter

of the whole instrument 375 mm. and the breadth of the bar 18 mm. The distance between the tips of the long curved and the short straight arms is 84 mm.

It is obvious that in attempting to determine the diameters of an aperture what we should engage to discover are the actual limits of the space enclosed by its margins and not distances between arbitrarily selected "points" on the sometimes blunt surfaces of these.[2] Not only does the new instrument greatly lessen the arbitrary factor in selecting such "points", but it also serves to save time by removing the necessity of fixing upon them. Its remaining uses require no description, and it need only be said that it has been fully tested on the cleaned skull as well as upon the living head and has in every way been found satisfactory.

The example shown in Figures 1 and 2 is made of stainless steel. This is a refractory medium to work in from the manufacturer's point of view and results in a somewhat heavy instrument. Future instruments will be manufactured in a lighter stainless metal.

We have to thank Mr. Walter Turnbull, head of the machine shop of New York University, Washington Square, New York, who at our instance undertook to construct the calipers, for his co-operation and for the ability with which he has executed a difficult task. Inquiries regarding the instrument should be addressed to Mr. Turnbull.

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will invariably coincide. The point is that by using a grosser unit when the characters are of inconsiderable dimensions, much relevant information is unnecessarily lost and some difficulty often occurs in securing an adequate distribution of the observed values if variabilities or correlations are to be computed from them. Moreover, a finer reading of small absolute measurements than is customarily attempted will remove any tendency towards a "lumping" of the indices of which they are components.

[2] The orbital height can be cited as an illustration. It is not desirable, however, to recommend the adoption of such a practice in the measurement of the nasal breadth. The sides of the pyriform aperture frequently slope outwards towards the margins and in the circumstances doubt is likely to arise concerning the extent to which the short arms of the instrument now described should be inserted to measure an internal breadth. In addition, no good purpose would be served by advocating a departure from the conventional method. So far as the foraminal length is concerned, the question of a strictly internal diameter need not be considered if a unique basion is defined as a terminal of this character, the basi-bregmatic height and the basi-nasal and basi-alveolar lengths. In this connexion, see Buxton and Morant, "The essential craniological technique," Part I, *Jour. Roy. Anthrop. Inst.*, Vol. 63, 1933, pp. 37-39.

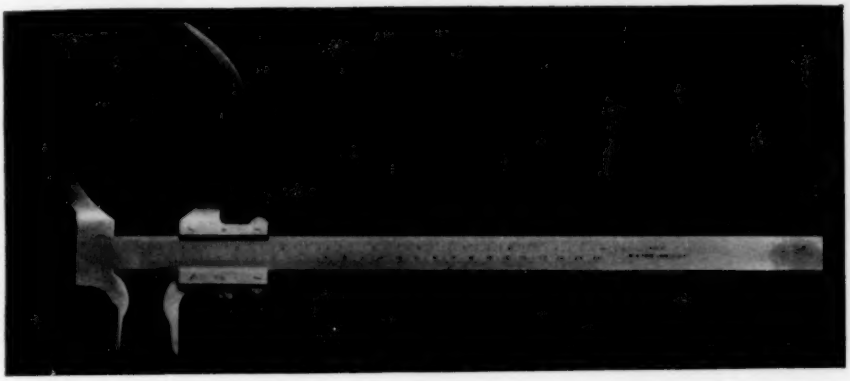

FIG. 1. ANTERIOR RELATION OF CALIPERS

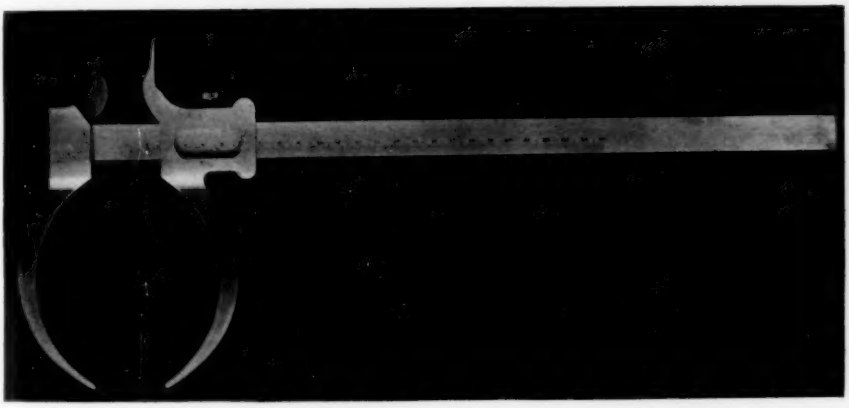

FIG. 2. POSTERIOR RELATION OF CALIPERS

RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

I. EVOLUTION AND GENETICS

1. *Evolution—General Principles*

ANDERMANN, FRIEDRICH. Irrtum und Wahrheit der Biologie. Kritik der Abstammungslehre. *Vienna, Leipzig and Bern* (Verlag für Medizin, Weidmann and Co.), 1937. Pp. 282. 9¼ × 6¼ inches. RM. 12 (paper); RM. 14 (cloth) [Bibliographic footnotes.]

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COX, E. W. The Evolution of the Australian Merino. *Sidney, New South Wales* (Angus and Robertson), 1936. Pp. xxii + 160 + 31 plates. 10 × 7¼ inches. 21s.

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MOLONY, HENRY J. C. Evolution Out of Doors. A Study of Sex Differences and Animal Coloration. Edited and with an appendix by J. R. de la H. Marett. Photographs by Cherry and John Kearton. *London* (Hutchinson's Scientific and Technical Publications), 1937. Pp. xx + 248 + 30 photographs. 8½ × 5½ inches. 15s. net. [Bibliography of 3¼ pages.]

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2. *Human Evolution*

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3. *Prehistory and Archaeology*

COLE, FAY-COOPER, and THORNE DEUEL. Rediscovering Illinois. Archaeological Explorations in and around Fulton County. *Chicago* (University of Chicago Press), 1937. Pp. xvi + 295 + 36 plates. 9½ × 6¾ inches. $2.00.

4. *Genetics—General Principles*

JENNINGS, H. S. Fundamental units in biology. *Science*, Vol. 84, pp. 445-450, 1936.

TIMOFÉEFF-RESSOVSKY, N. W. Experimentelle Mutationsforschung in der Vererbungslehre. Beeinflussung der Erbanlagen durch Strahlung und andere Faktoren. *Dresden and Leipzig* (Verlag von Theodor Steinkopff), 1937. Pp. x + 181. 9 × 6 inches. RM. 15 (paper); RM. 16.50 (cloth). [Bibliography of 28 pages.]

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II. GROUP BIOLOGY

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2. *Public Health and Hygiene*

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